Is the river health concept useful for water management purposes?

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Overview

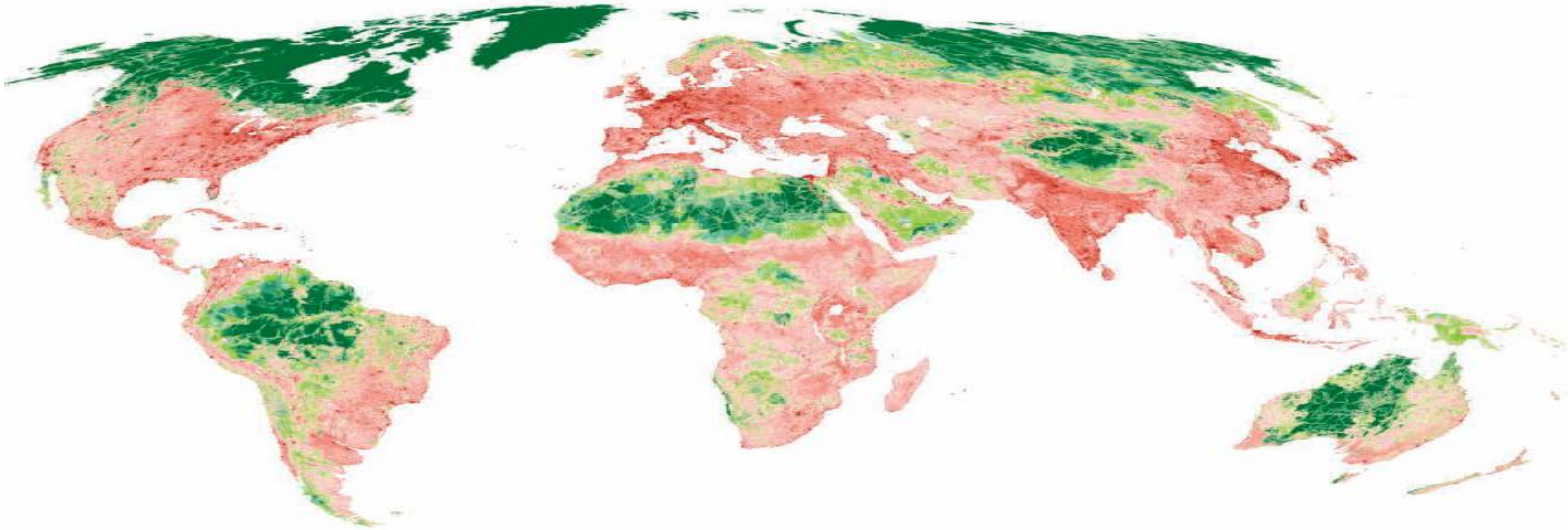
- Introduction
- River health and other concepts
- „Health system” – reference approach
- „Illness” – reasons and ways to improve
- „Precautions” - predictions of ecosystems status
- Conclusions

The thing takes place in the Anthropocene …

Key

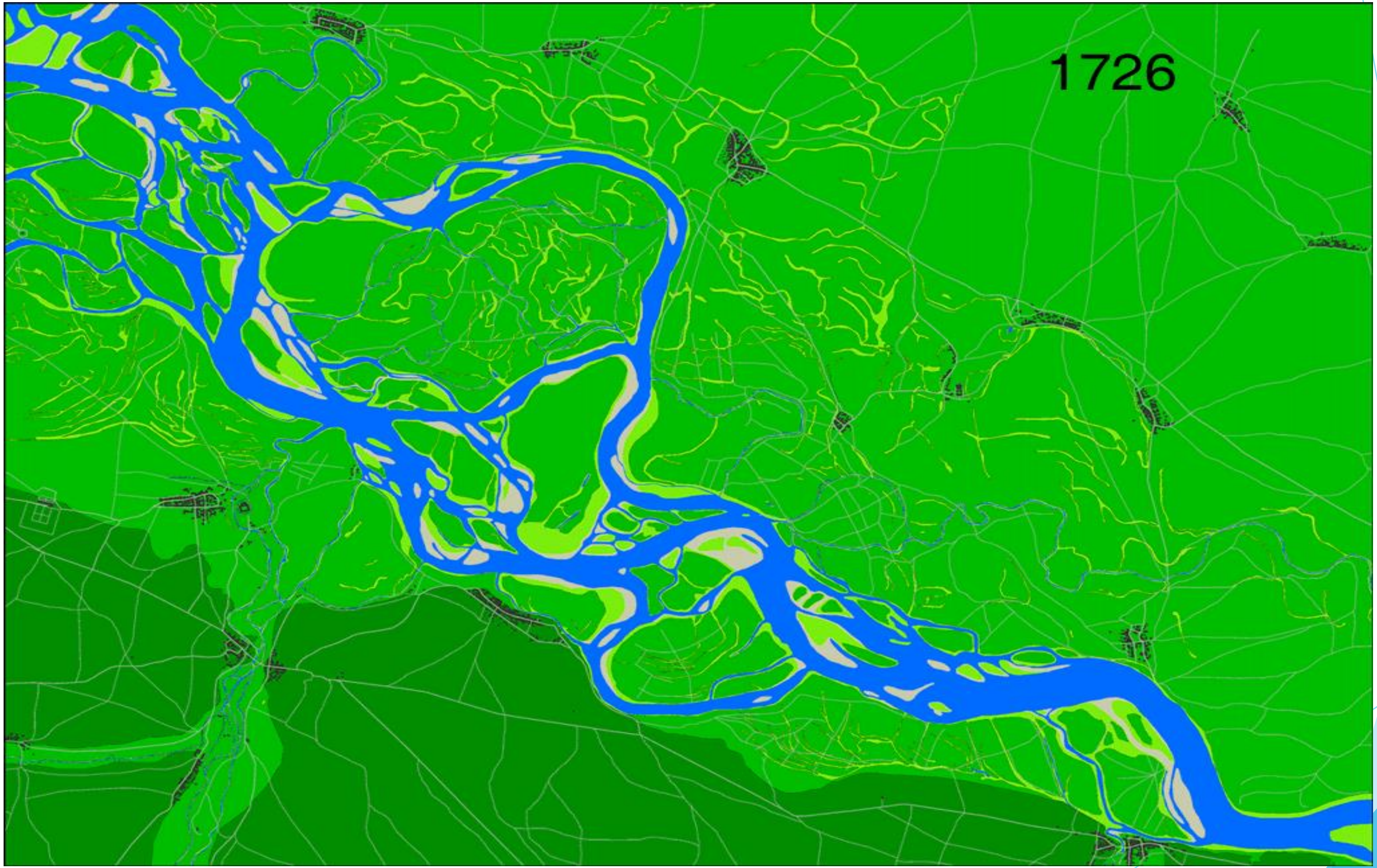
Damaged	Intact	Wilderness
High: 50	High: 1	High: 0
Low: 4	Low: 4	Low: 1

Figure 19:
The proportion of each terrestrial biome (excluding Antarctica) considered wilderness (dark green, human footprint value of <1), intact (light green, human footprint value of <4), or highly modified by humanity (red, human footprint value of > or equal to 4)[74].



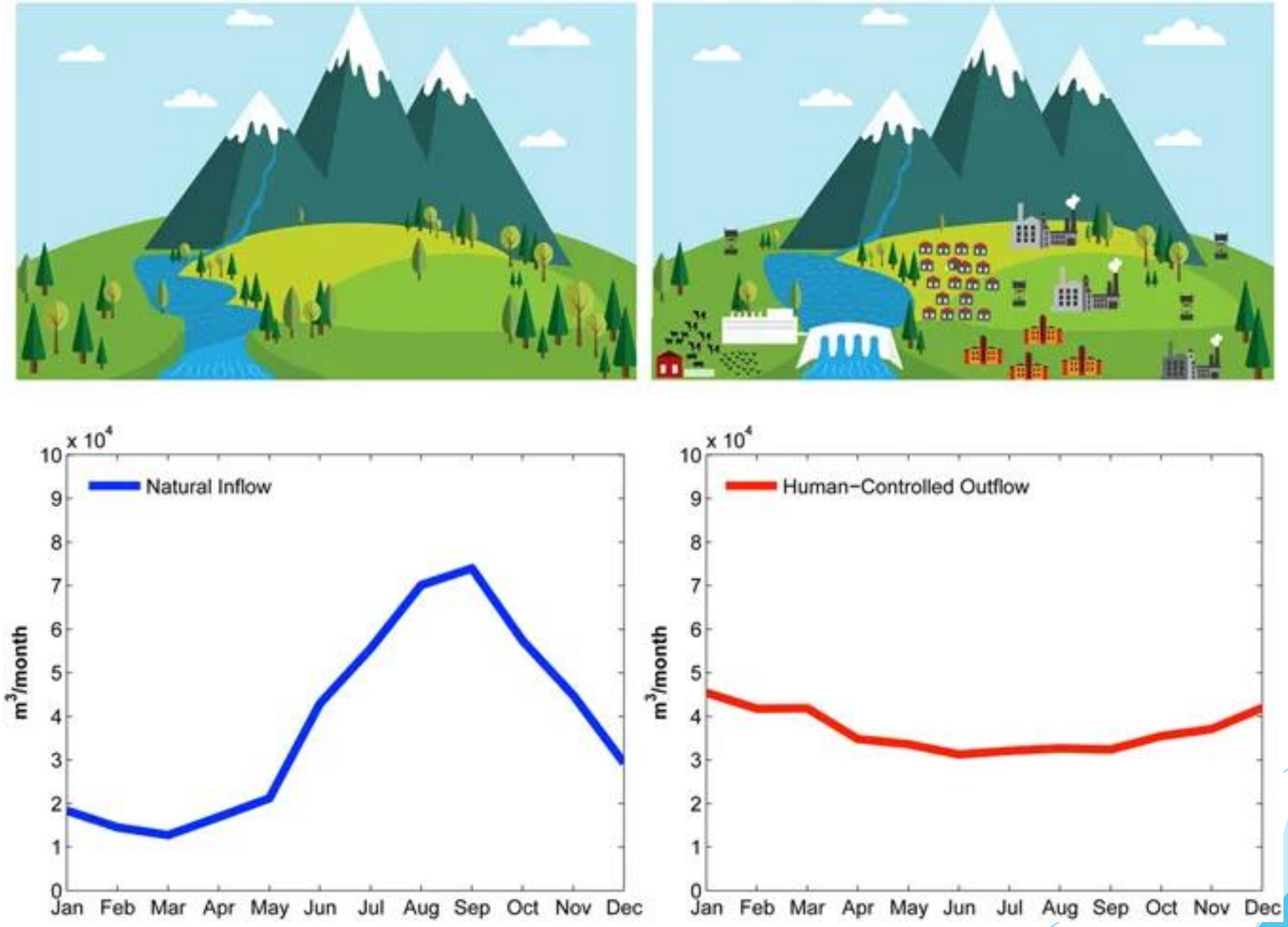
WWF LIVING PLANET REPORT 2020

Historical development Danube near Vienna 1726 – 2001



Hohensinner, S. & Eberstaller-Fleischanderl, D. (2004)

Accounting for anthropopression... or water resources in the Anthropocene?



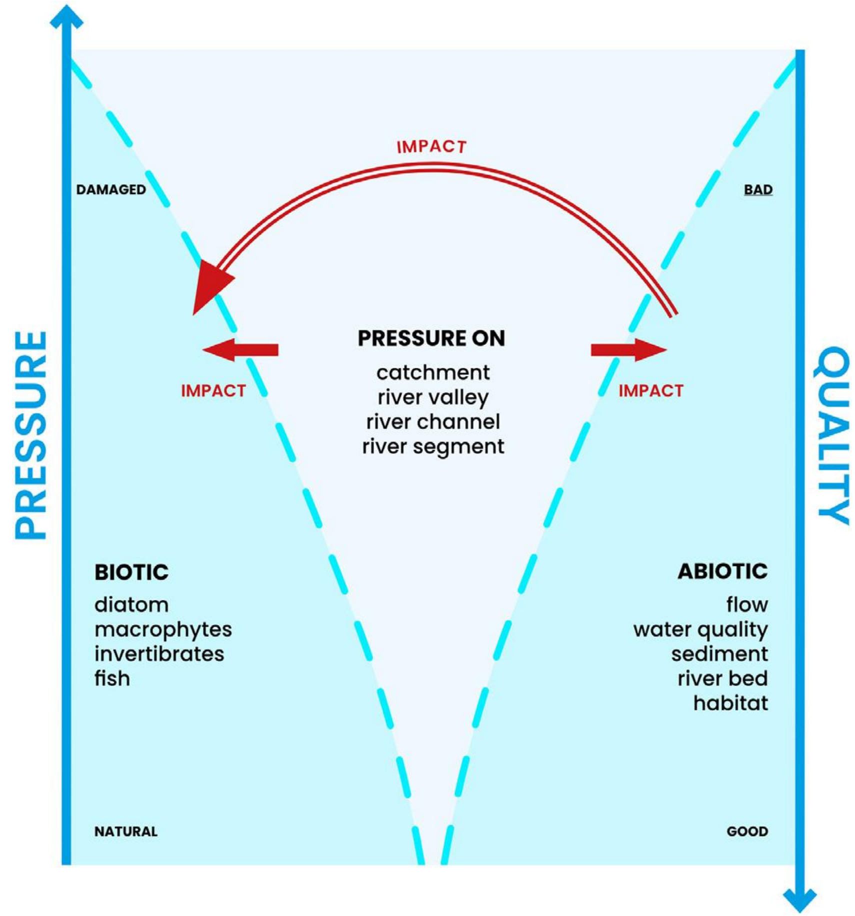
Ali Mehran, et al., Scientific Reports **Volume 7**, Article number: 6282 (2017)

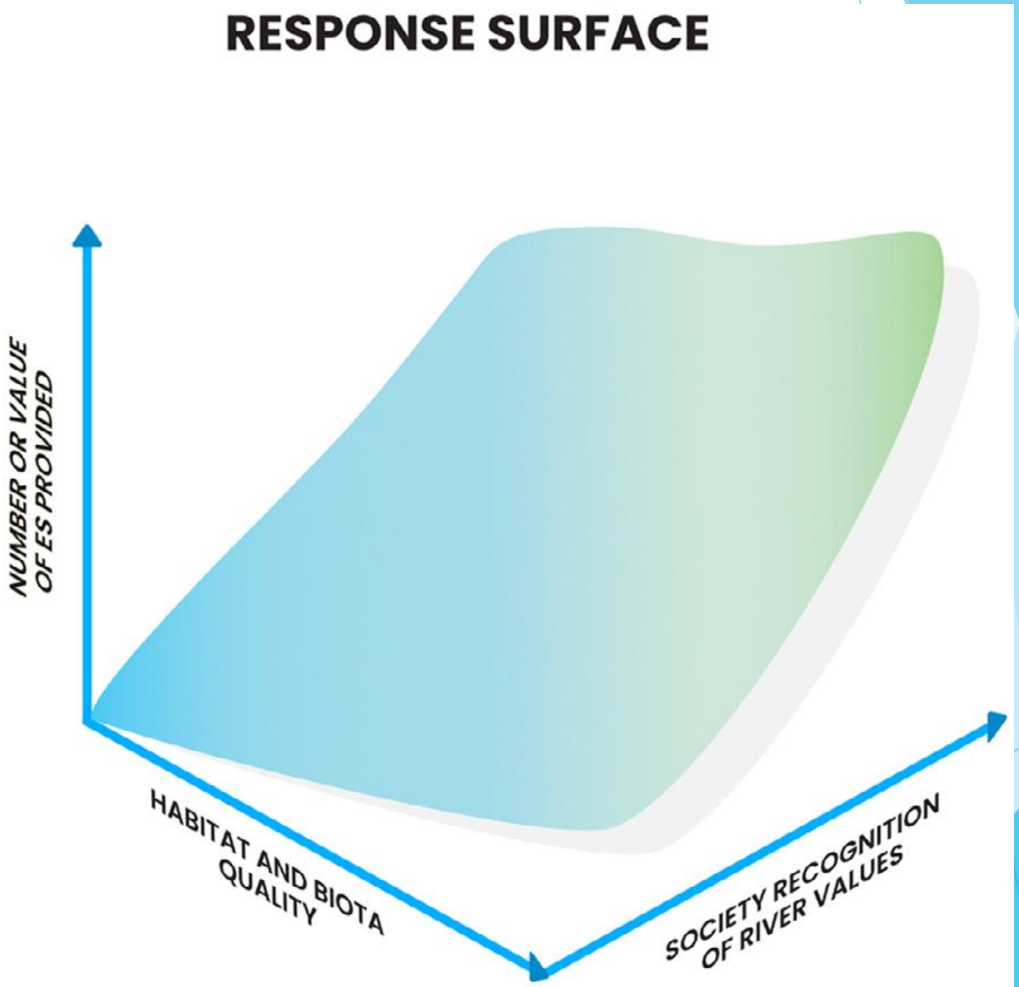
Concepts

River Health

- The term “river health” was introduced around 30 years ago and applied to assessing river conditions. It was seen as analogous to human health, offering the general public a better understanding of ecological challenges in freshwater systems. However, it was unclear how rivers' physical, chemical, and biological characteristics may be integrated into conservation or restoration measures. In this respect, we declare a healthy river ecosystem “*that is sustainable and resilient, maintaining its ecological structure and function over time while continuing to meet societal needs and expectations.*” In the EU context, the similarity, in a sense, but focused on the river term “good ecological status,” has been defined and forms a central point of the Water Framework Directive.

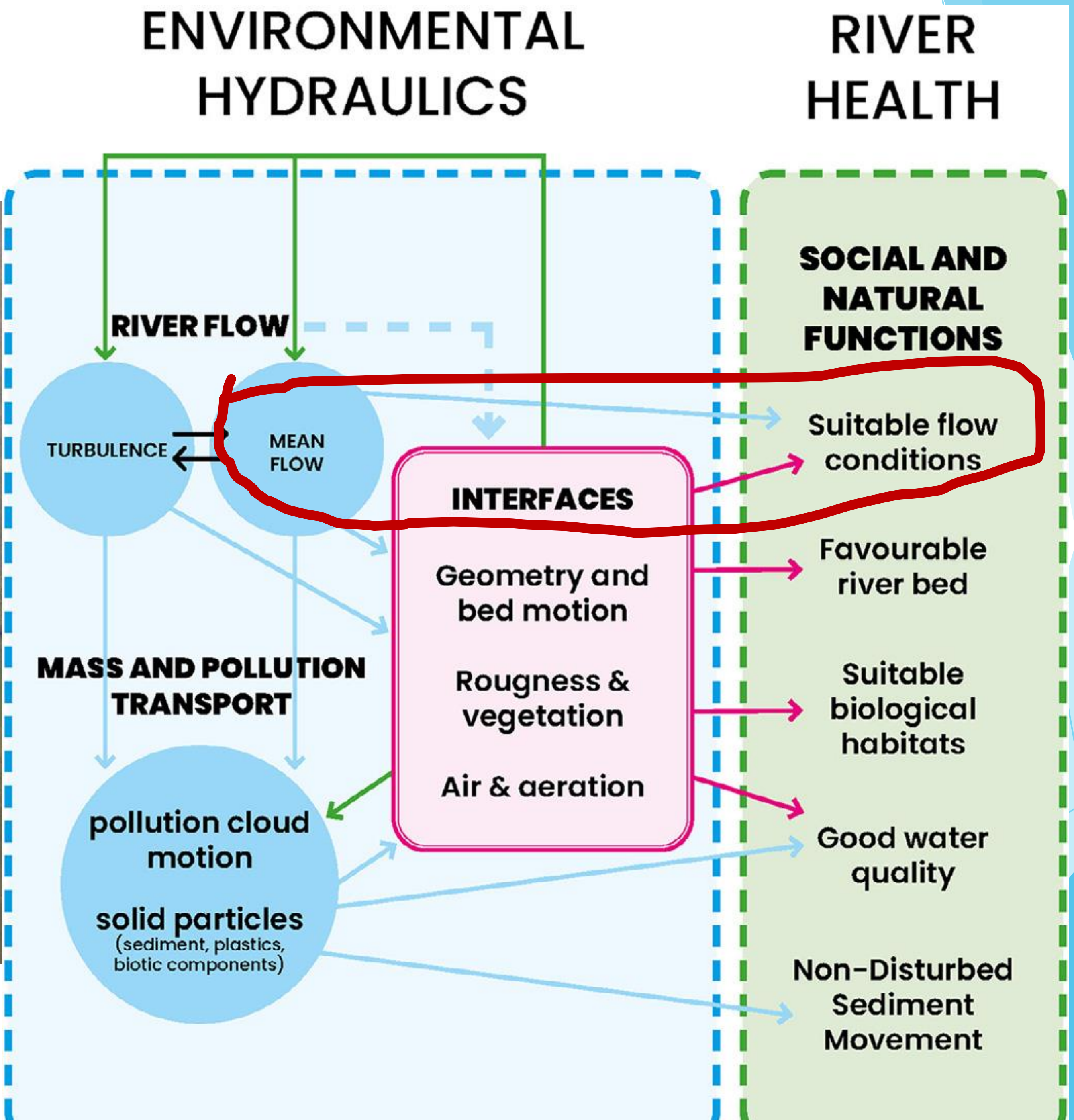
River Health 2





Environmental hydraulics research for river health: recent advances and challenges
Paweł Rowinsk , Tomasz Okruszko, Artur Radecki-Pawlik, E&H, 2022

River Health 3



Environmental hydraulics research for river health: recent advances and challenges
Paweł Rowinsk , Tomasz Okruszko, Artur Radecki-Pawlik, E&H, 2022

River continuum concept (Vannote et al. 1980)

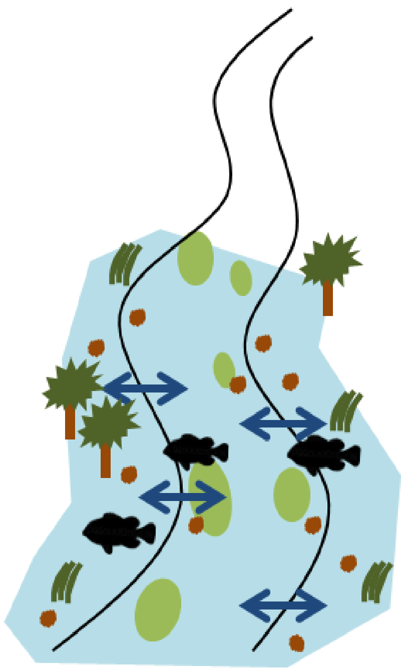
Focusses on the longitudinal connectivity along the river.

Upstream:
Narrow, shading, high flow, macrophytes limited, allochthonous Corg

Middle:
Wider, more light, low flow, macrophytes abundant, authochthonous Corg

Downstream:
Too wide and deep, less light, higher flow, macrophytes limited, suspended matter

Flood Pulse Concept
(Junk et al. 1989)



Describes the lateral connection between the river and its floodplain

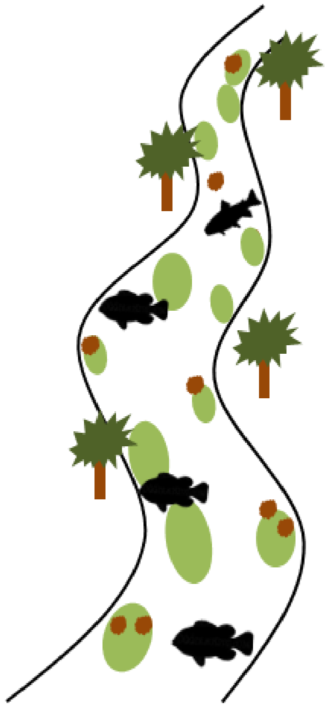
Floodplain material is main source

Can be temporarily (e.g. winter flooding)

First developed for tropical rivers (Amazon, Okavango Delta , Pantanal)

Riverine productivity model (Thorp & Delong 1994)

riverine productivity concept

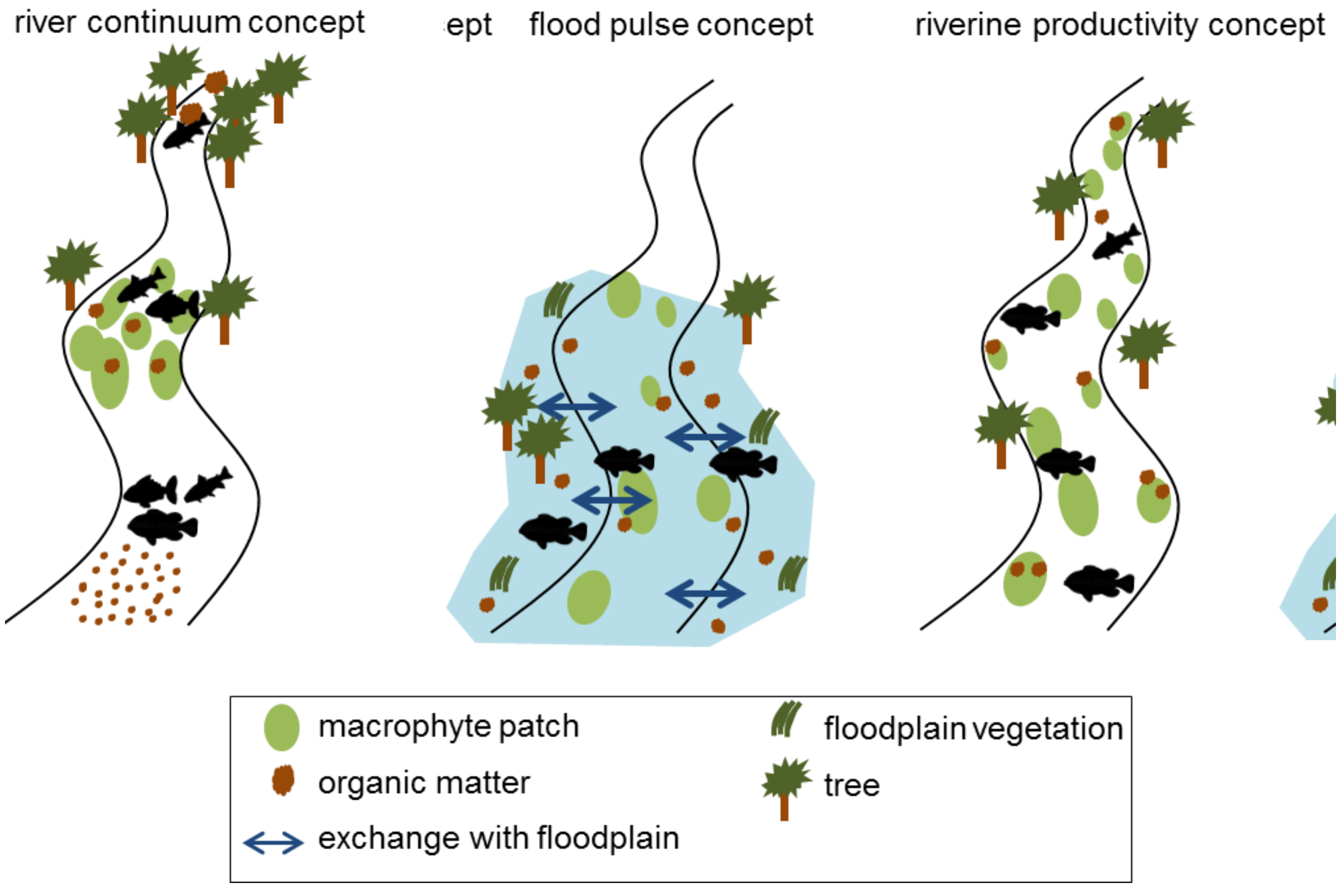


Puts local instream primary production and riparian leaf fall central

Corg from (far) upstream is not nutritional enough anymore

Local primary production (e.g. algae) can still be substantial

Different habitats ~ physical conditions



RCC: headwater streams and small rivers
FPC: large floodplain rivers
RPM: large rivers with restricted channels

River types

After A MULTI-SCALE HIERARCHICAL FRAMEWORK FOR DEVELOPING UNDERSTANDING OF RIVER BEHAVIOUR TO SUPPORT RIVER MANAGEMENT.
A.M. Gurnell[1]*,

THERE ARE COMPLEX MULTI-SCALE CONTROLS ON RIVER-FLOODPLAINS

THE HYDROMORPHOLOGY OF NATURALLY-FUNCTIONING RIVERS IS DRIVEN BY:

i. Regional characteristics: particularly climate
ii. Catchment characteristics: translate properties of the regional climate into flows of water and sediment,
iii. Valley setting: dictates topographic slope and lateral confinement of river reaches,
iv. Reach properties: moderate response to flows of water and sediment from upstream (bank / bed sediment calibre and structure, aquatic and riparian vegetation).
v. Ecosystem engineering by plants: affects character and dynamics of reaches and habitats.

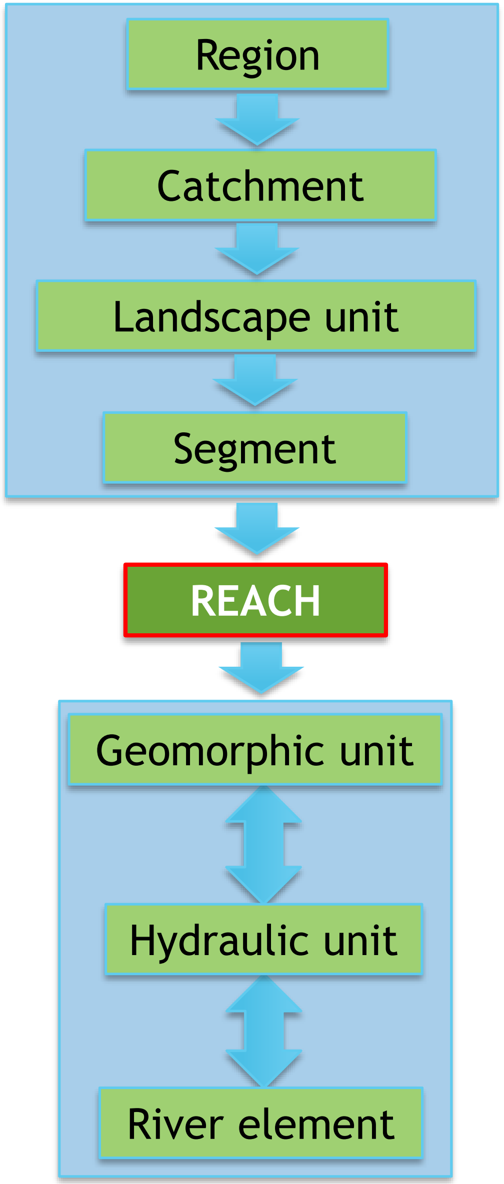
RESULT: REACH HYDROMORPHOLOGICAL ASSEMBLAGE & DYNAMICS

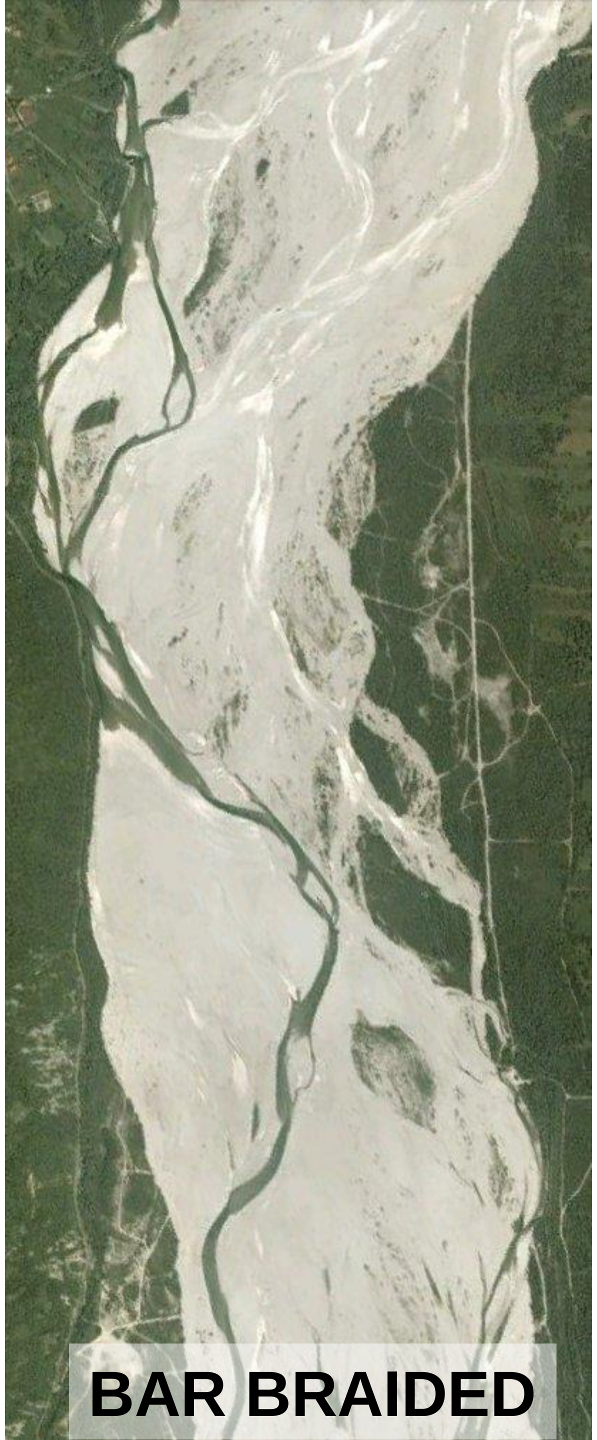
SPATIAL HIERARCHICAL FRAMEWORK

CONTROLS ON RIVER BEHAVIOUR (affect delivery of water and sediment to river reaches)

RIVER AND FLOODPLAIN TYPE, DYNAMICS, SENSITIVITY

DYNAMIC SUITE OF RIVER AND FLOODPLAIN FEATURES (PHYSICAL HABITATS)

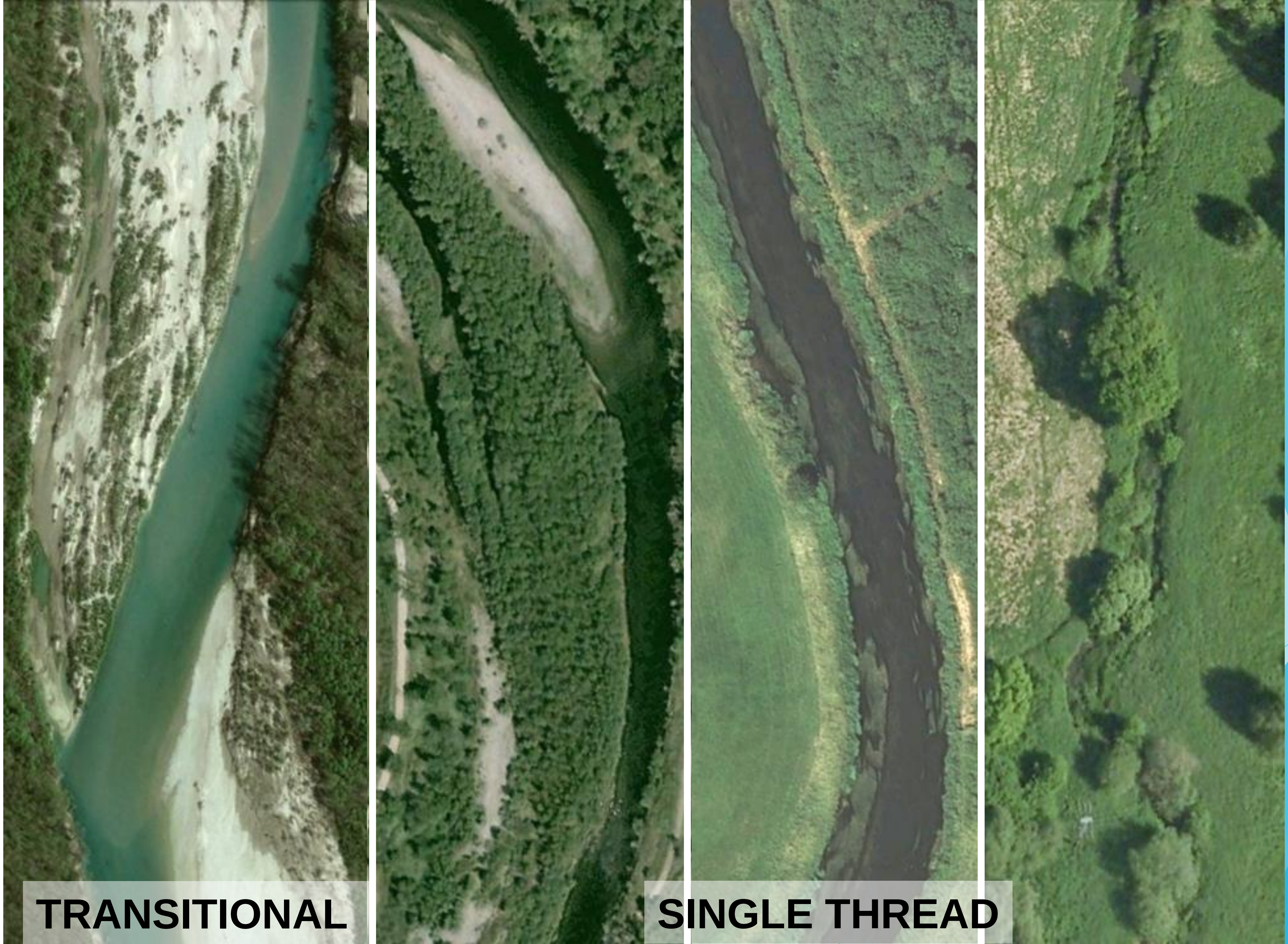


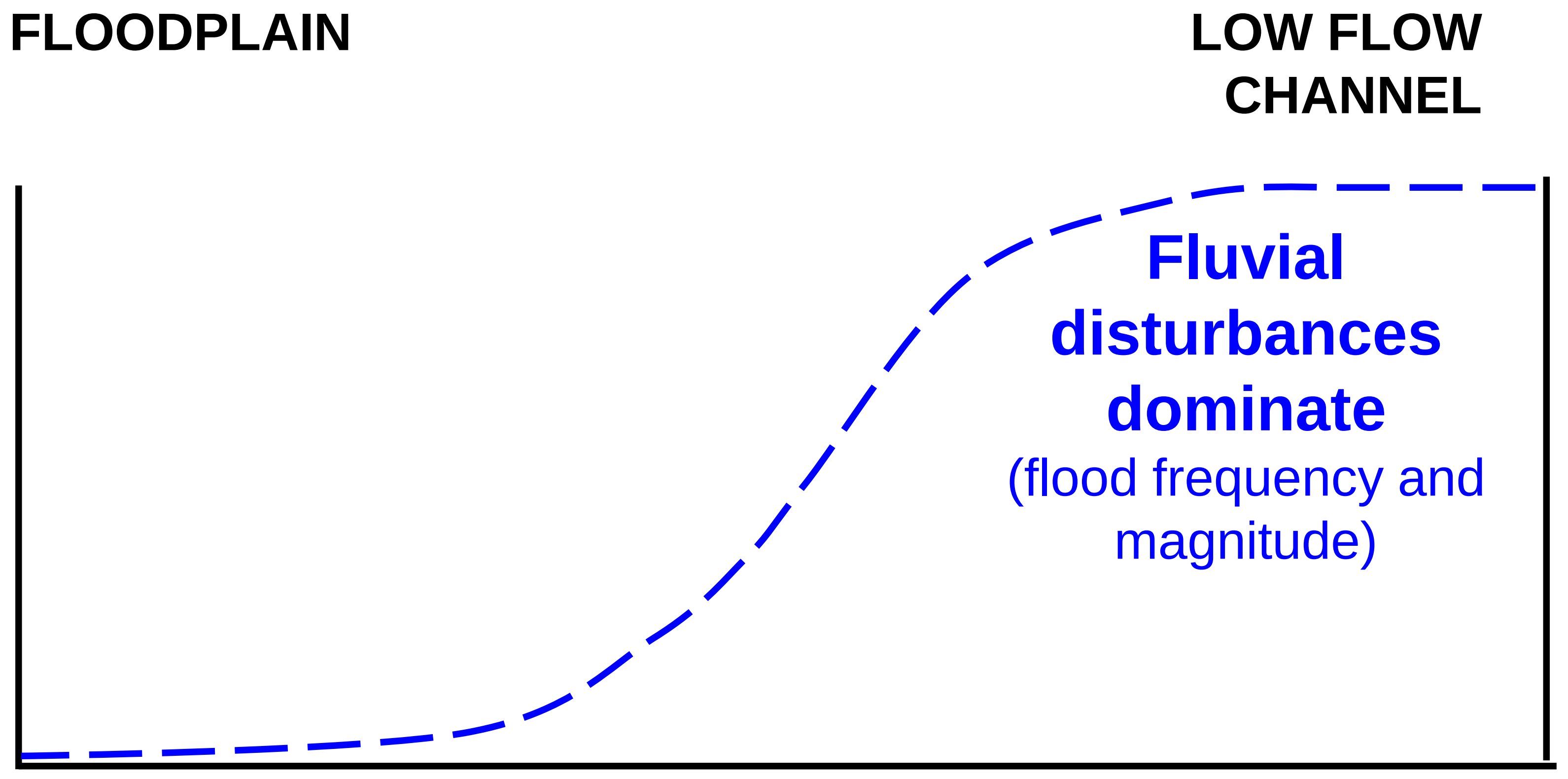


BAR BRAIDED

ISLAND BRAIDED

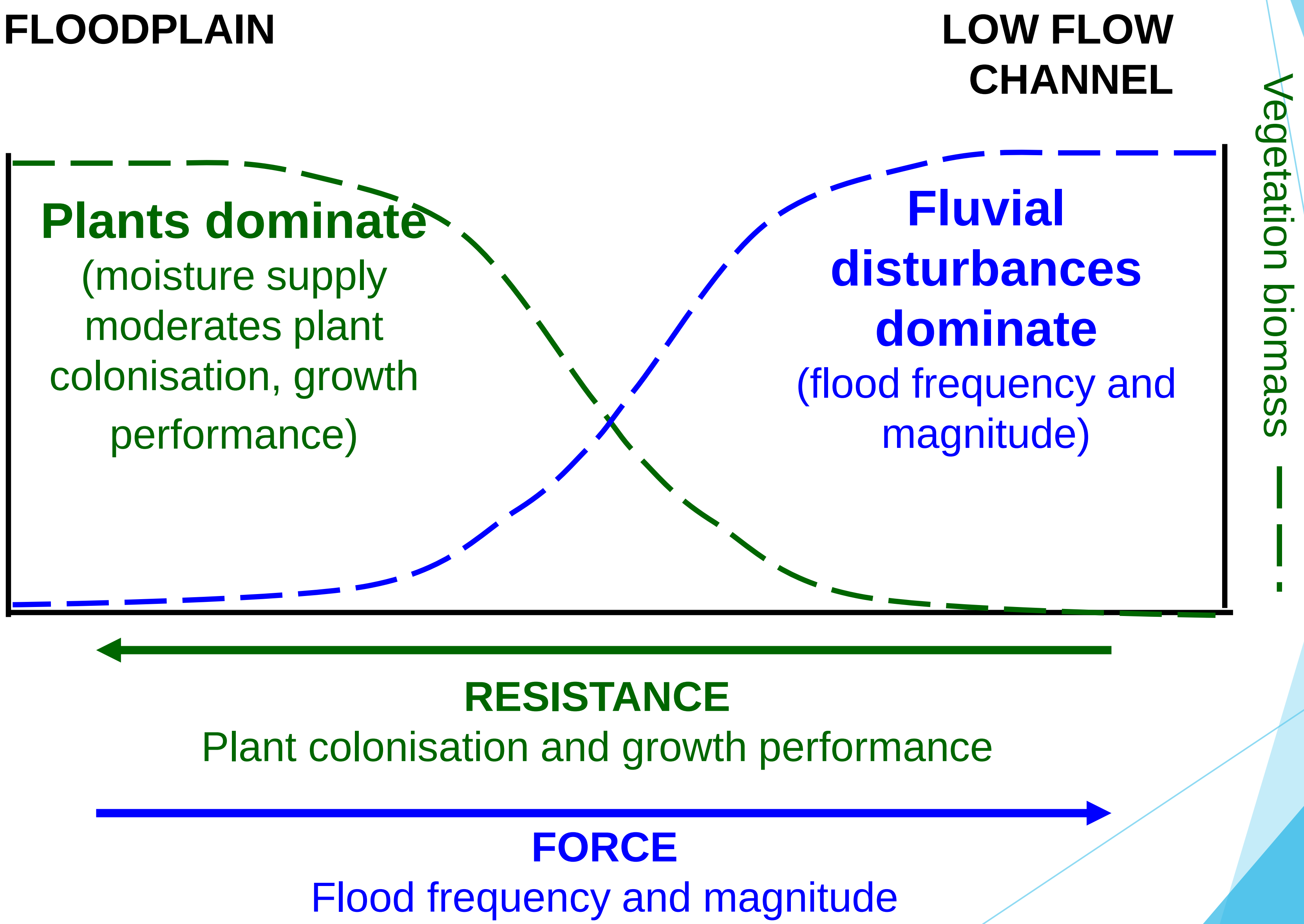
TRANSITIONAL


TRANSITIONAL
SINGLE THREAD

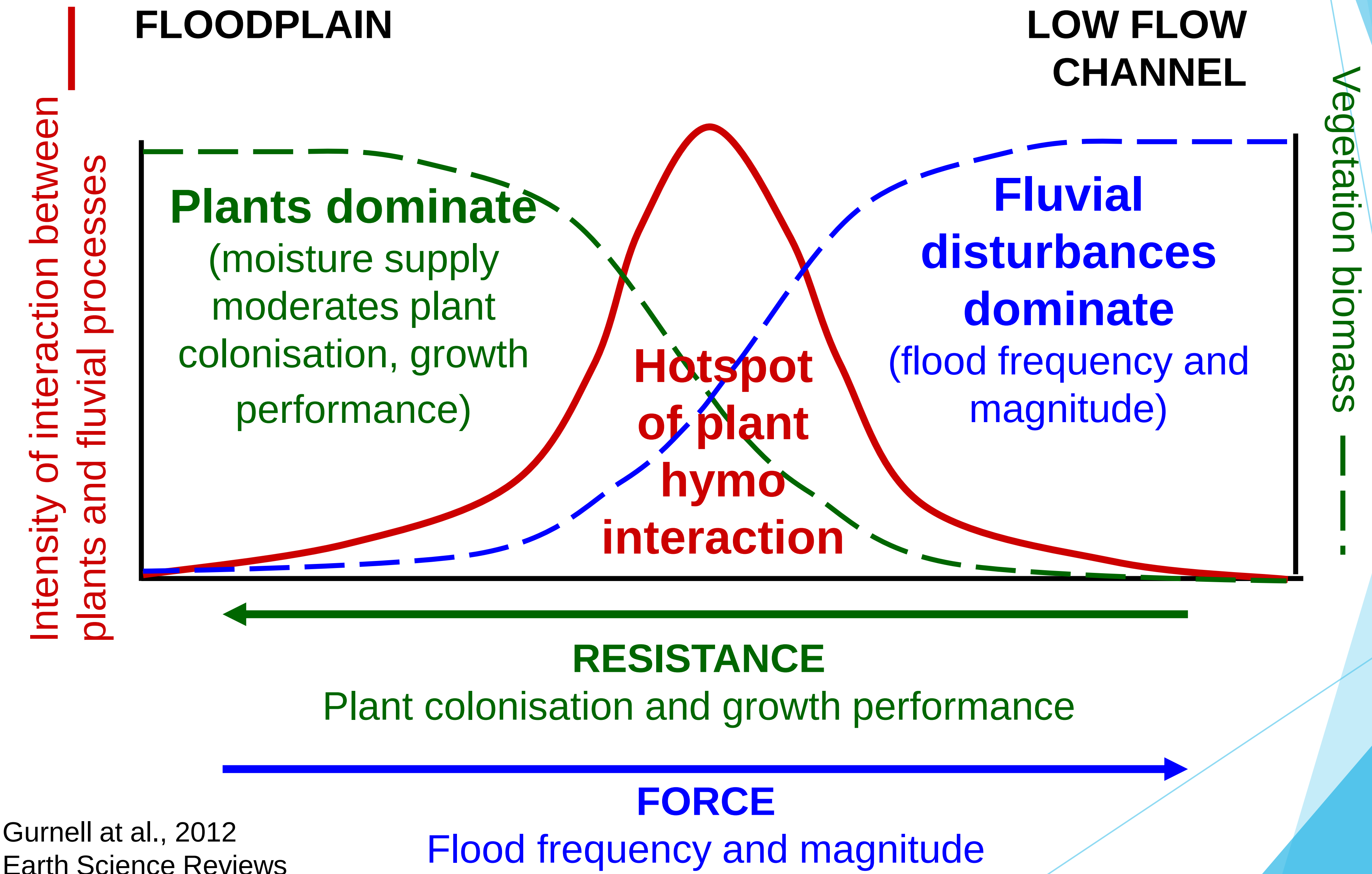


FORCE

Flood frequency and magnitude

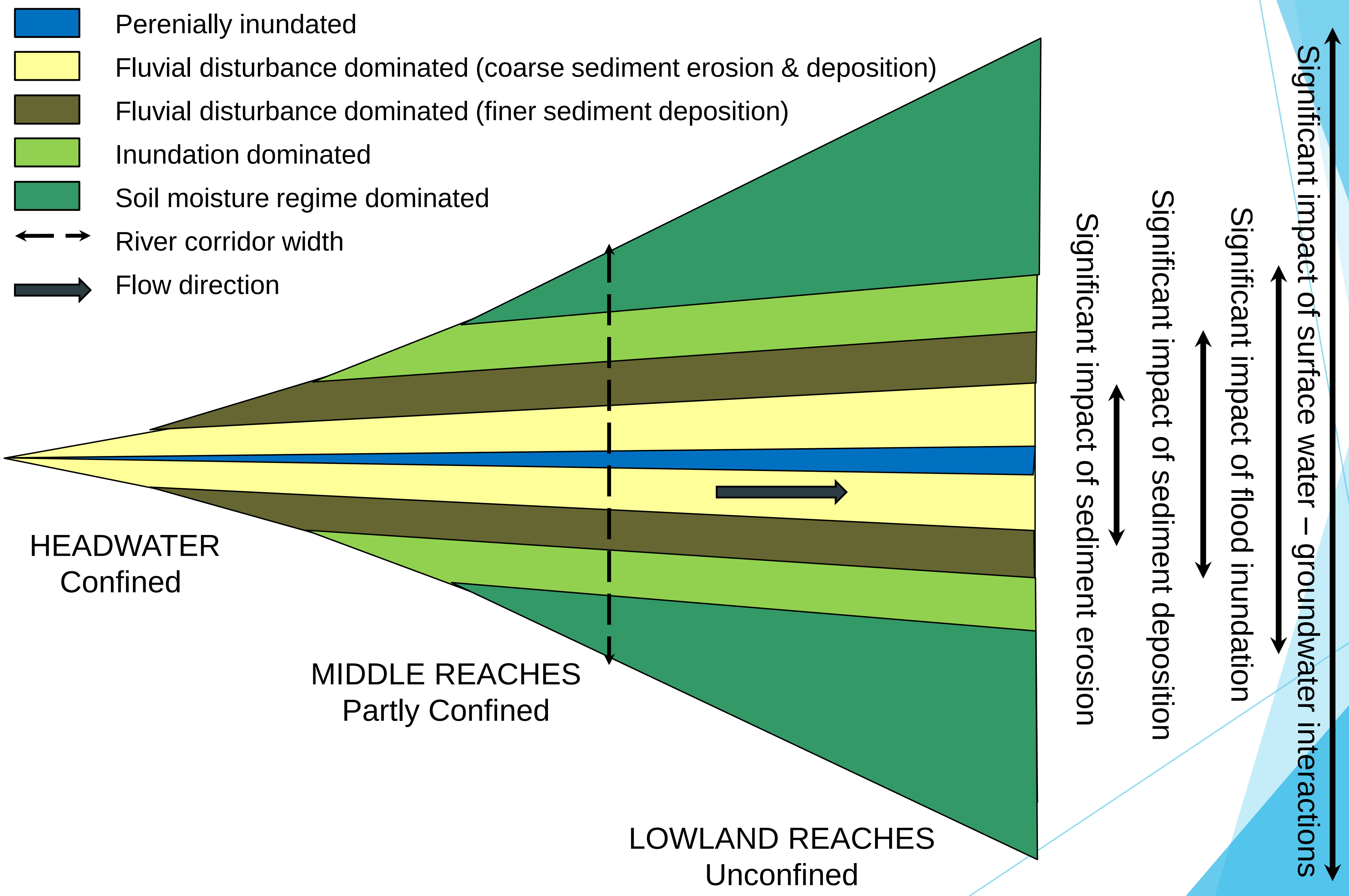


FLOODPLAIN
LOW FLOW CHANNEL
Plants dominate
(moisture supply moderates plant colonisation, growth performance)
Fluvial disturbances dominate
(flood frequency and magnitude)
Vegetation biomass
RESISTANCE
Plant colonisation and growth performance
FORCE
Flood frequency and magnitude

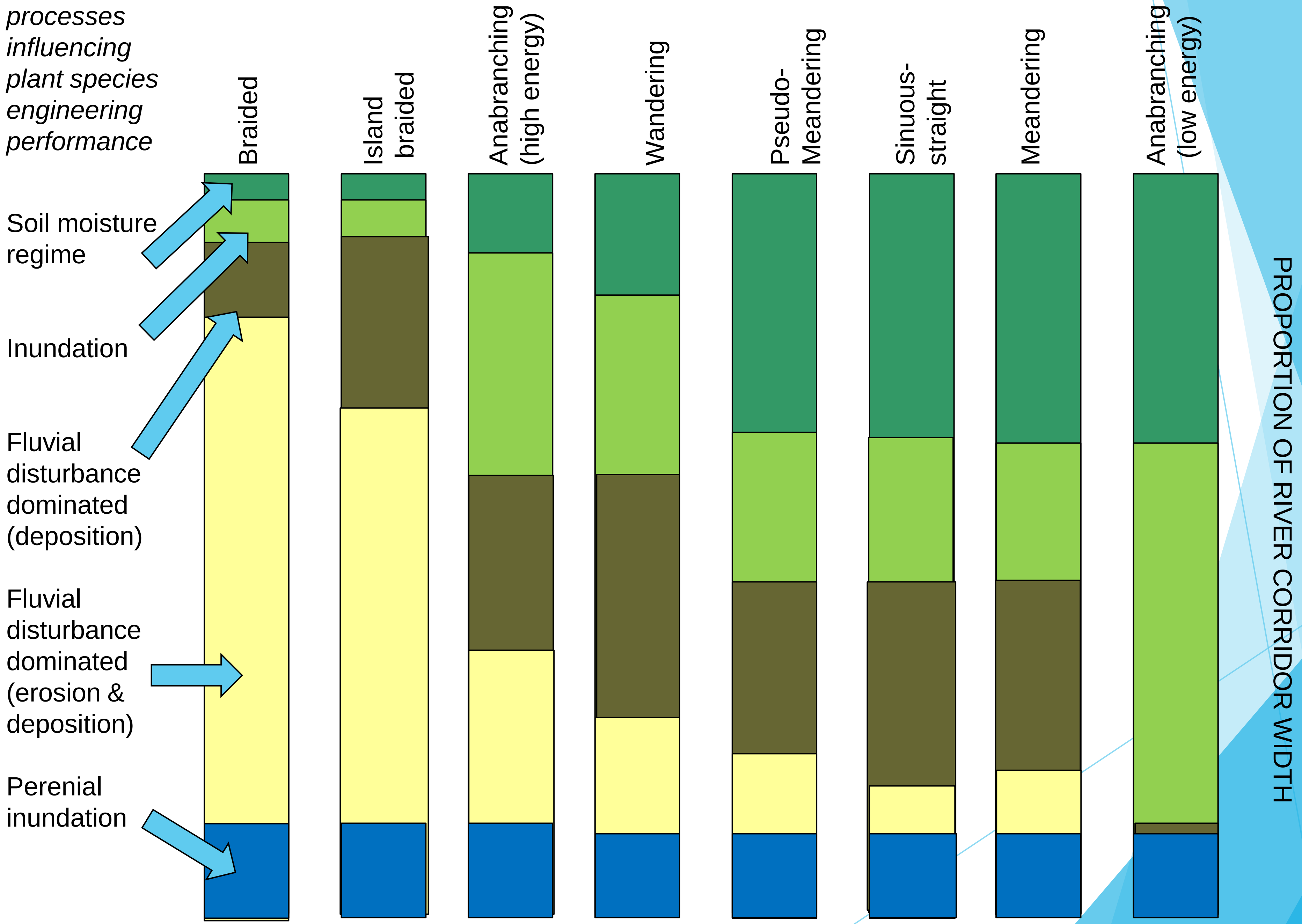


Gurnell at al., 2012
Earth Science Reviews

Plant - Physical Process Interactions: 1. Upstream to Downstream, 2. Laterally



Plant - Physical Process Interactions: 3. River – Floodplain Type



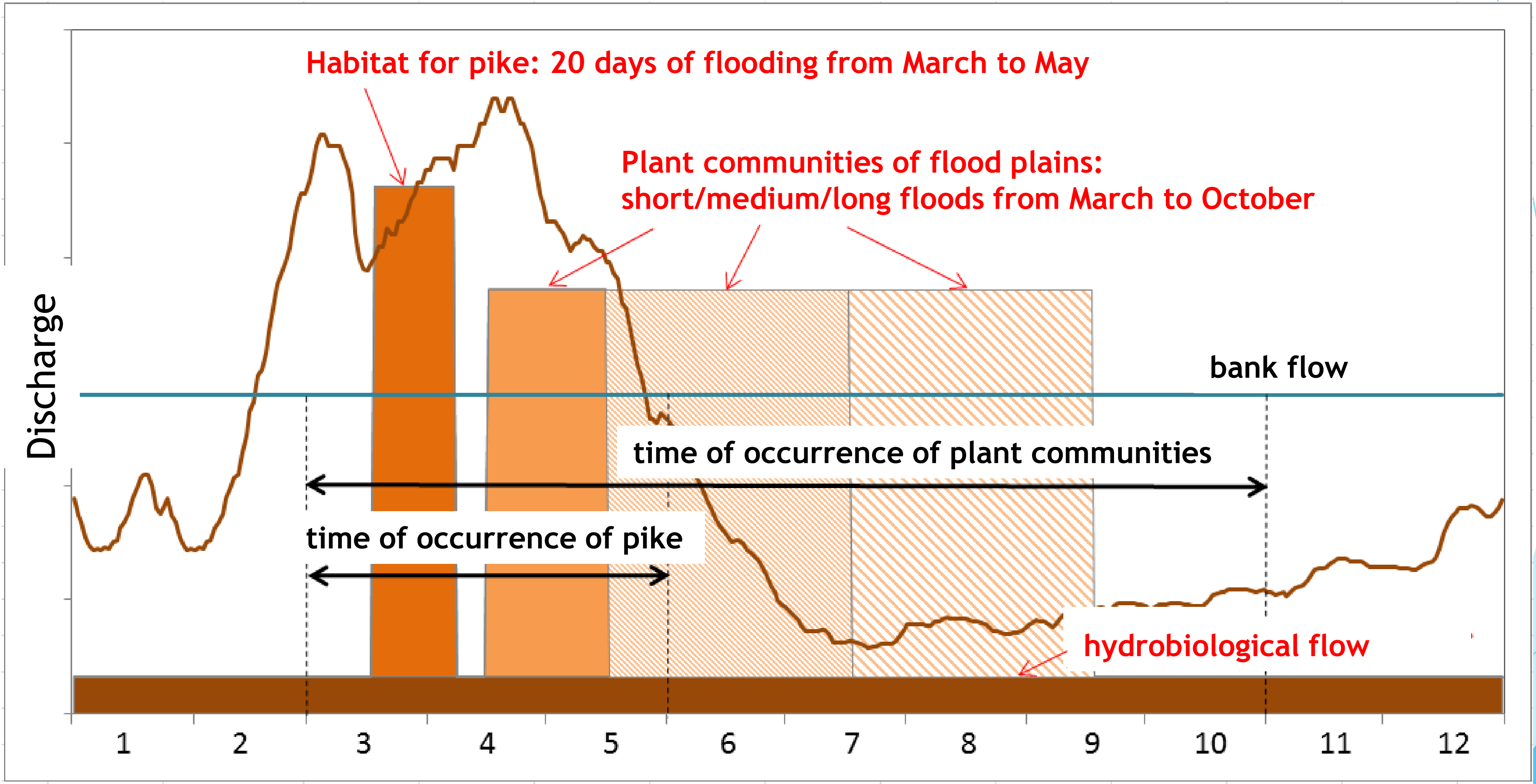
Evironmental flow

- Environmental flows (e-flows), also called ecological flows or biological flows, can be defined as the hydrological regime required to sustain river and associated water dependent ecosystems, as well as the human livelihoods depending on them More specifically, e-flows covers both the quantity and quality of water required spatially and temporally to maintain desired river ecosystem conditions. They have been typically defined as the minimum amount of water required for a river, but more recently, e-flow science has evolved towards the idea that flow regime should be as natural as possible, and capture low and high flows, flow variability, rates of change, seasonality, etc. *E-flows are essentially the river environmental water requirements* (Edwards et al. 2021).

Evironmental flow

Environmental flow is the water regime provided within a river, wetland or coastal zone to maintain ecosystems and their benefits where there are competing water uses and where flows are regulated (IUCN 2003).

Building blocks method to capture e-flows



scheme after Piniewski, 2012

IHA parameters

- Indicators of Hydrological Alteration (IHA) is a desktop technique for defining environmental flow requirements introduced by Richter *et al*. (1996, 1997). This approach recognizes that all characteristics of the flow …
- The IHA … egime providing … five classifica… ate of change.

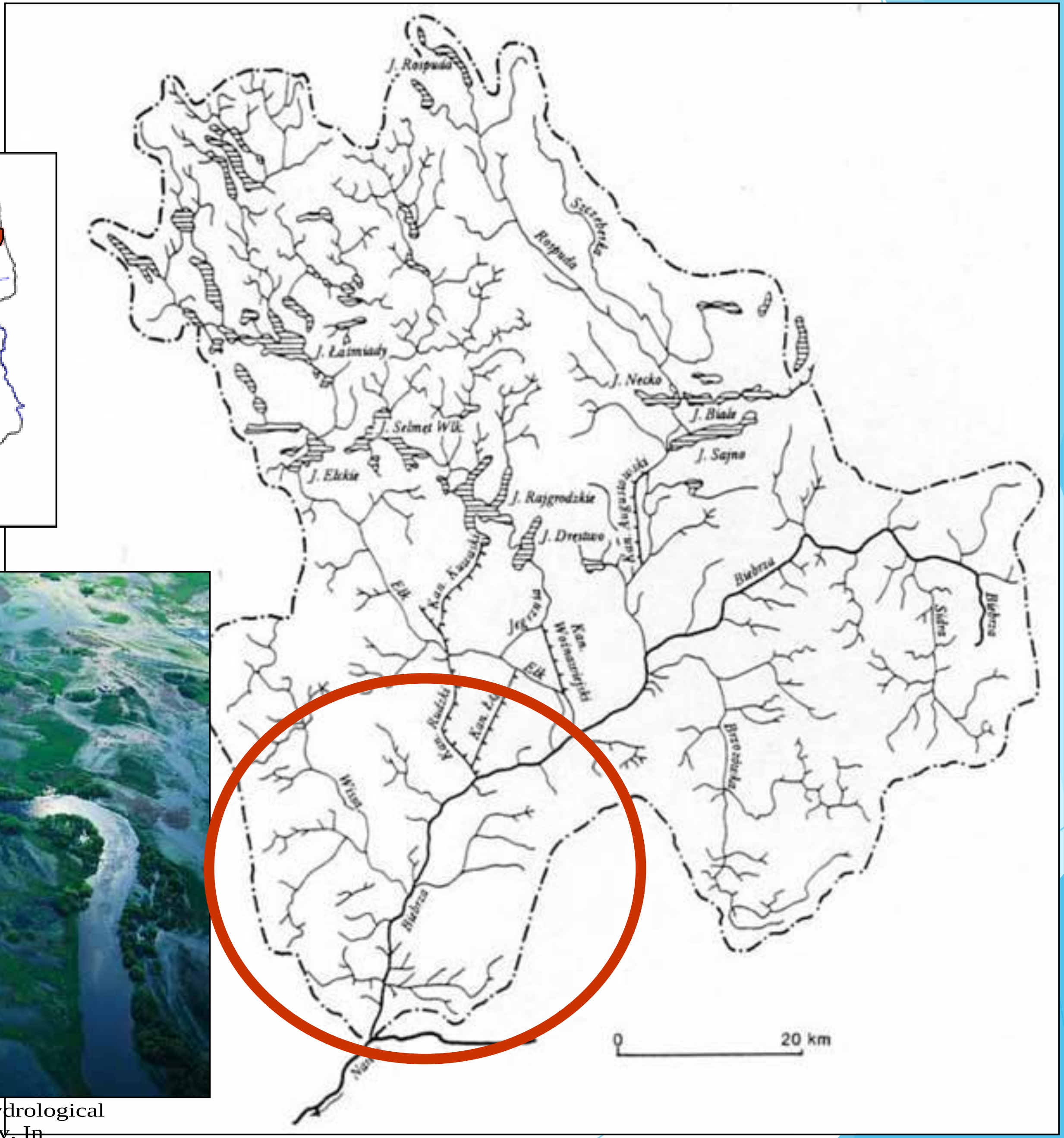
Table 5.3: Quantitative criteria to assess the departure from naturalness of the flow regime (1 – discharge near natural to 5 – Discharge greatly altered) - Source: CEN, 2010.

% days flow different from natural in spring, summer, autumn or winter (worst)	<20	20-<40	40-<60	60-<80	≥80
<5% decrease or <10% increase in flow	1	1	1	2	2
5-<15% decrease in flow or 10-<50% increase in flow	1	2	2	3	3
15-<30% decrease in flow or 50-<100% increase in flow	1	2	3	3	4
30-<50% decrease in flow or 100-<500% increase in flow	1	2	3	4	5
≥50% decrease in flow' or ≥500% increase in flow	2	3	4	5	5

- On the basis of the literaturę review, we may assess which IHA parameters are ecologically relevant.

Reference

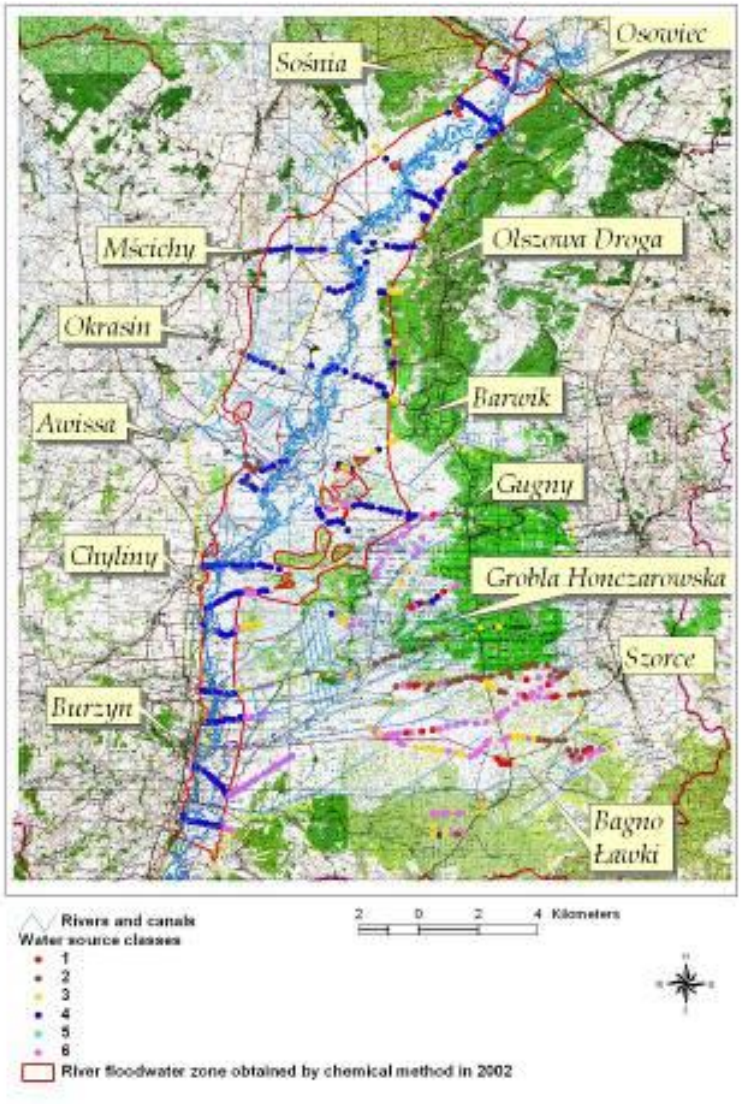
Biebrza Wetlands

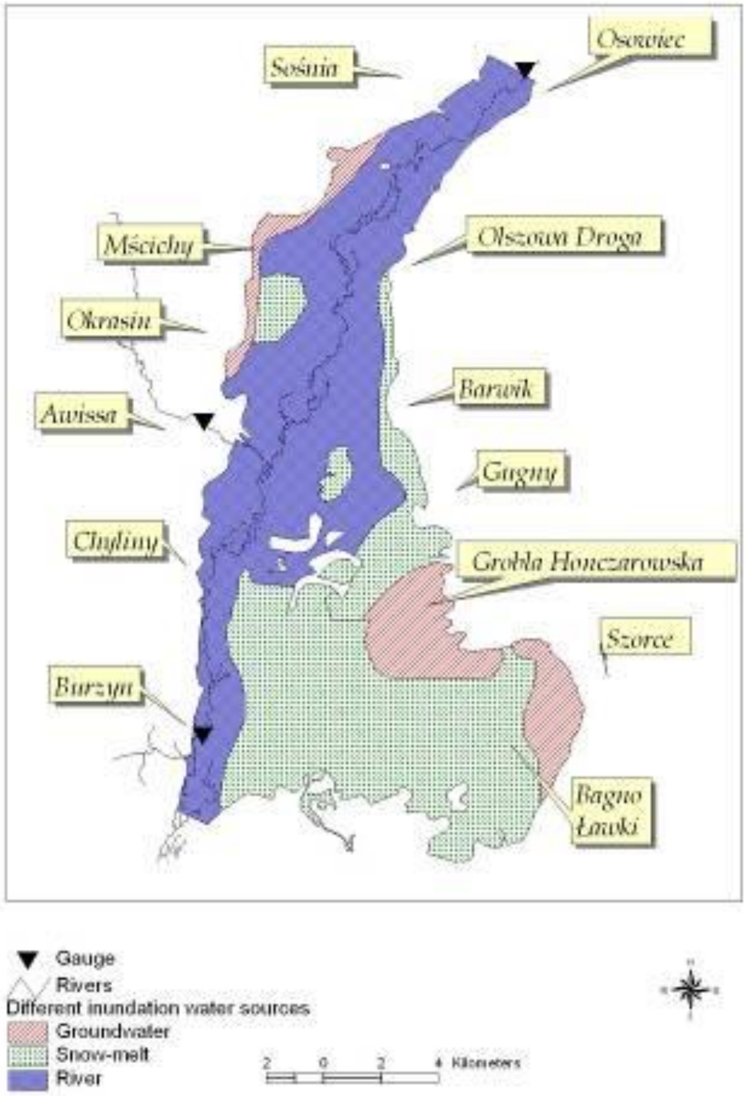


Okruszko, T., Chormański, J., Mirosław-Świątek, D., Gregorczyk, M., 2010. Hydrological characteristics of swamp communities, the Biebrza River (NE Poland) case study. In Christodoulou& Stamou (eds). Environmental Hydraulics, Taylor & Francis Group, London, pp. 407-412.

Vegetation of the riparian wetlands

Results of chemical analysis



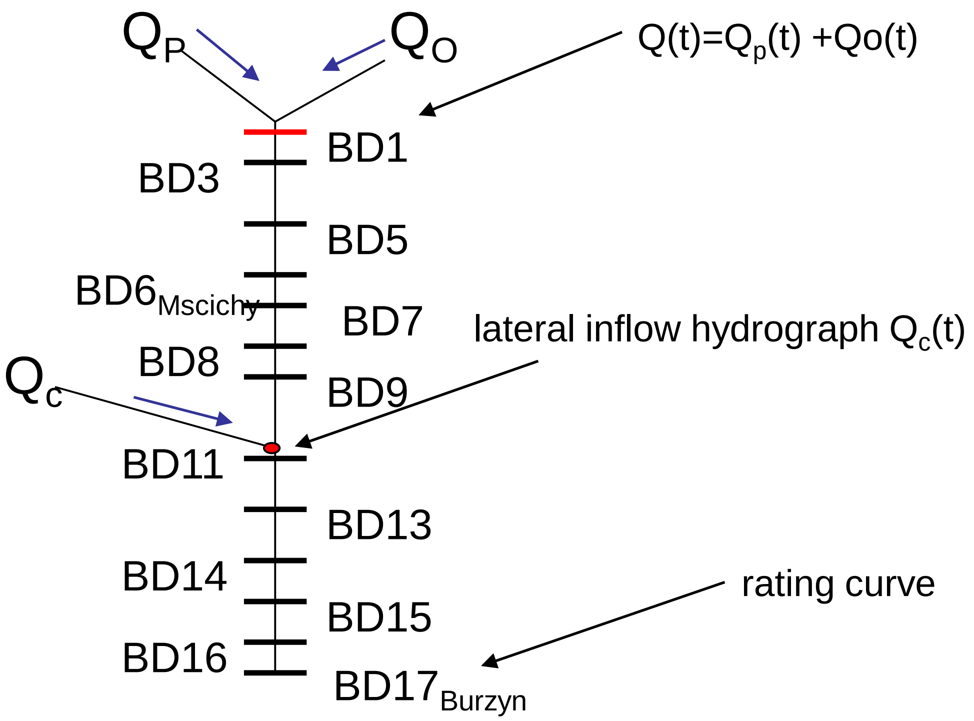


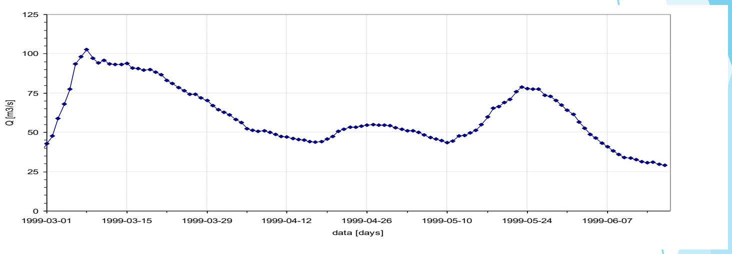
Chromanski et al, Ecological Engineering, 2011

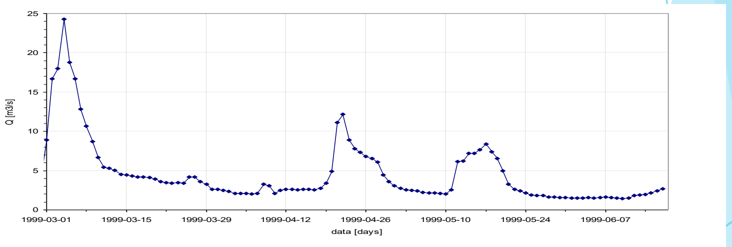
Hydraulic model topological scheme

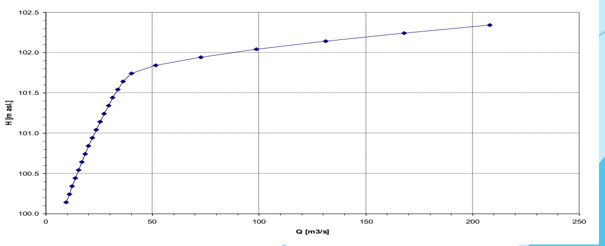
Unsteady 1-D hydraulic model – Full St. Venant equations

Boundary conditions

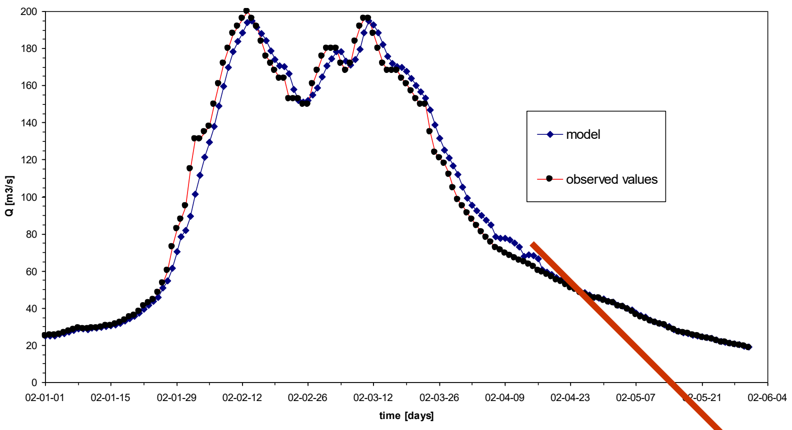








Results of hydraulic model

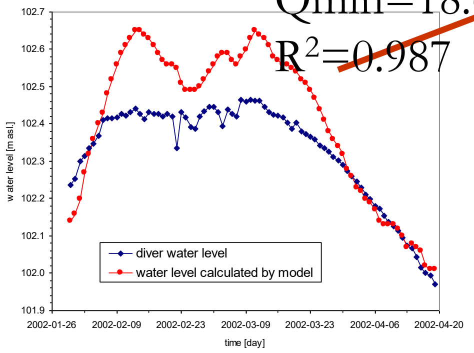


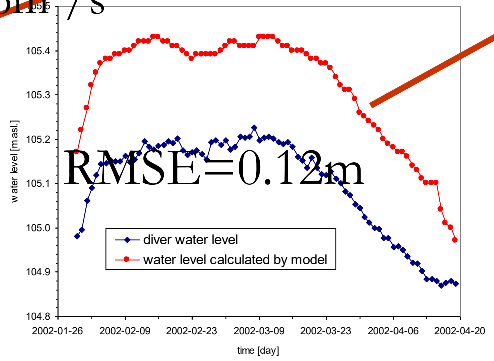
RMSE=6.89m^3/s

Qmax=200m^3/s

Qmin=18.6m^3/s

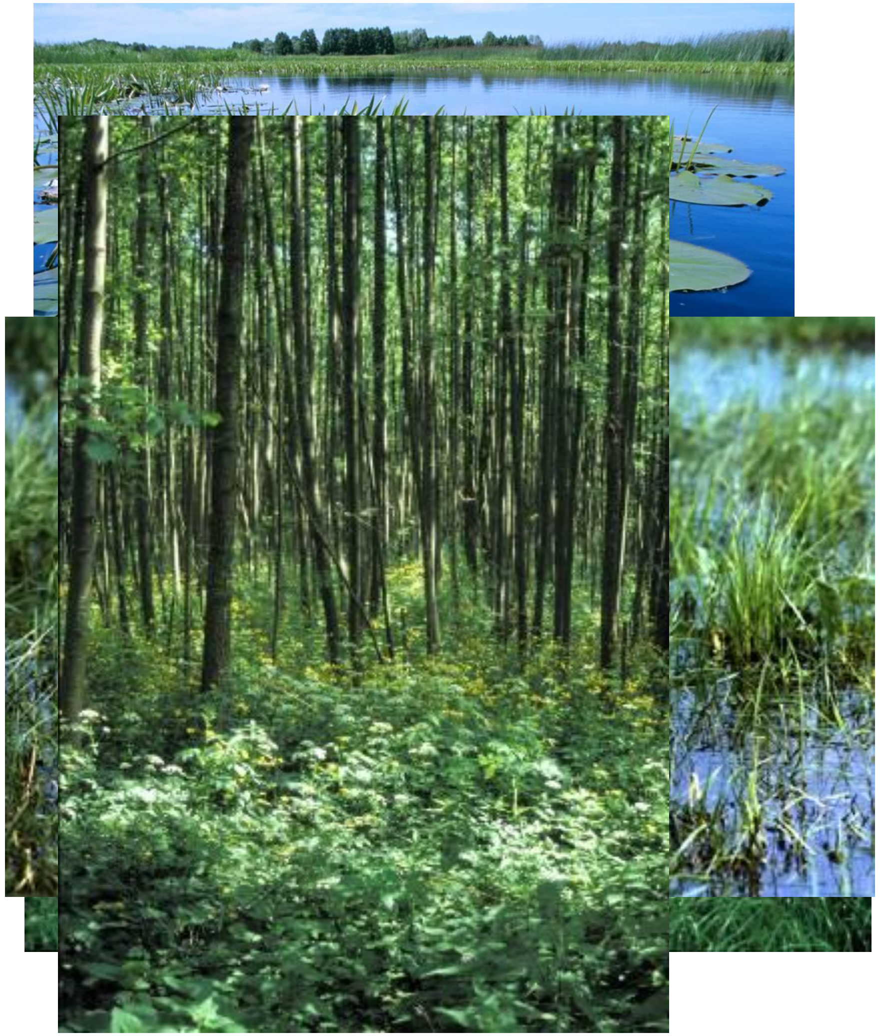
R^2=0.987

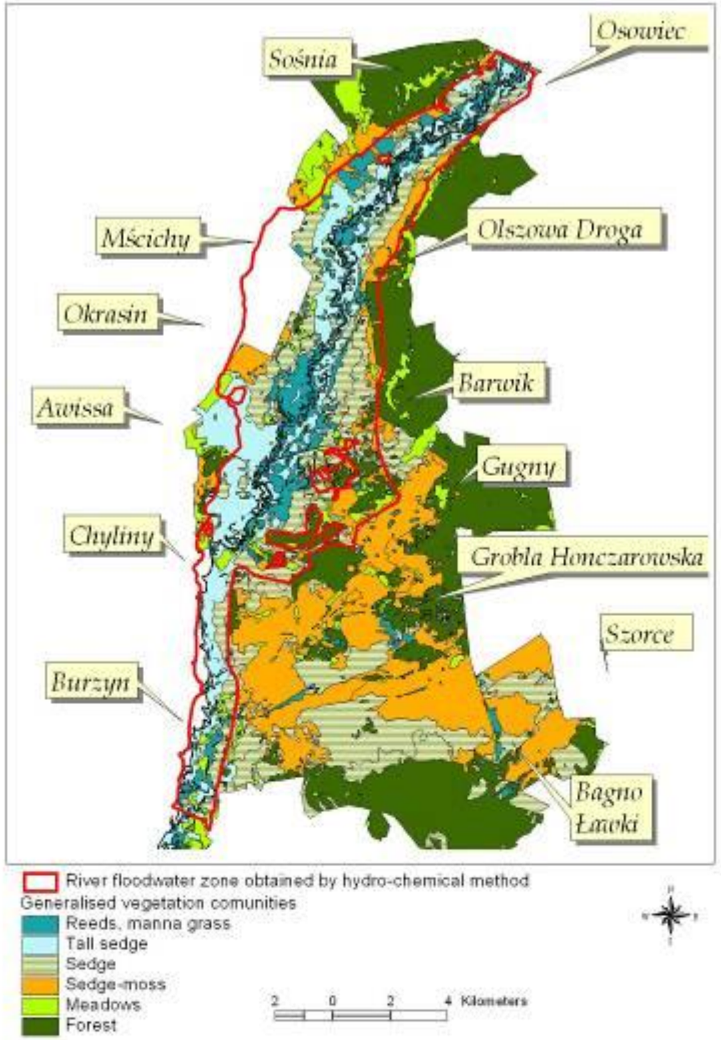


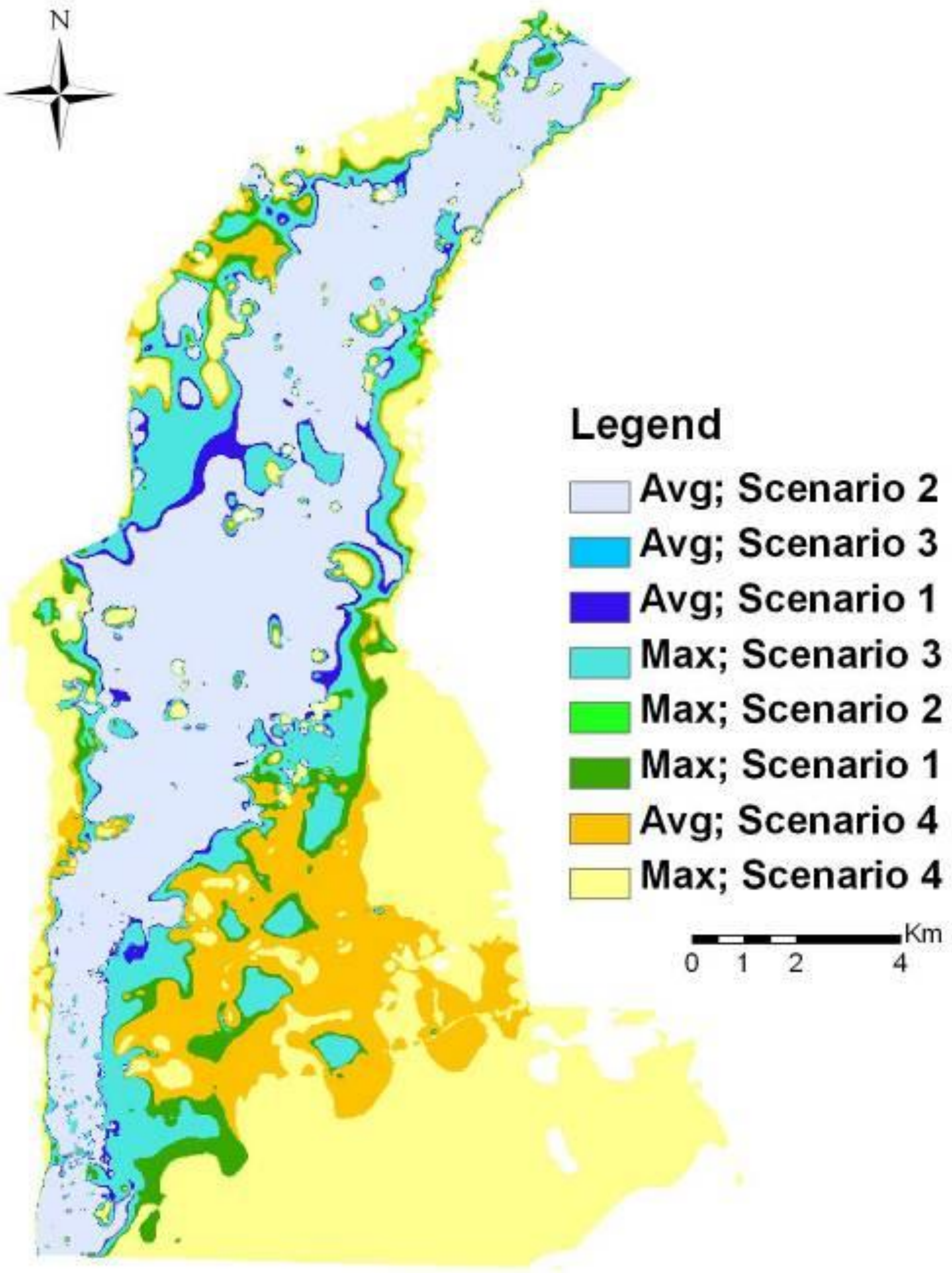


RMSE=0.12m

RMSE=0.22m




Osowiec
Sośnia
Mścichy
Olszowa Droga
Okrasin
Barwik
Awissa
Gugny
Chyliny
Grobla Honczarowska
Szorce
Burzyn
Bagno Ławki
River floodwater zone obtained by hydro-chemical method
Generalised vegetation comunities
Reeds, manna grass
Tall sedge
Sedge
Sedge-moss
Meadows
Forest
2 0 2 4 Kilometers

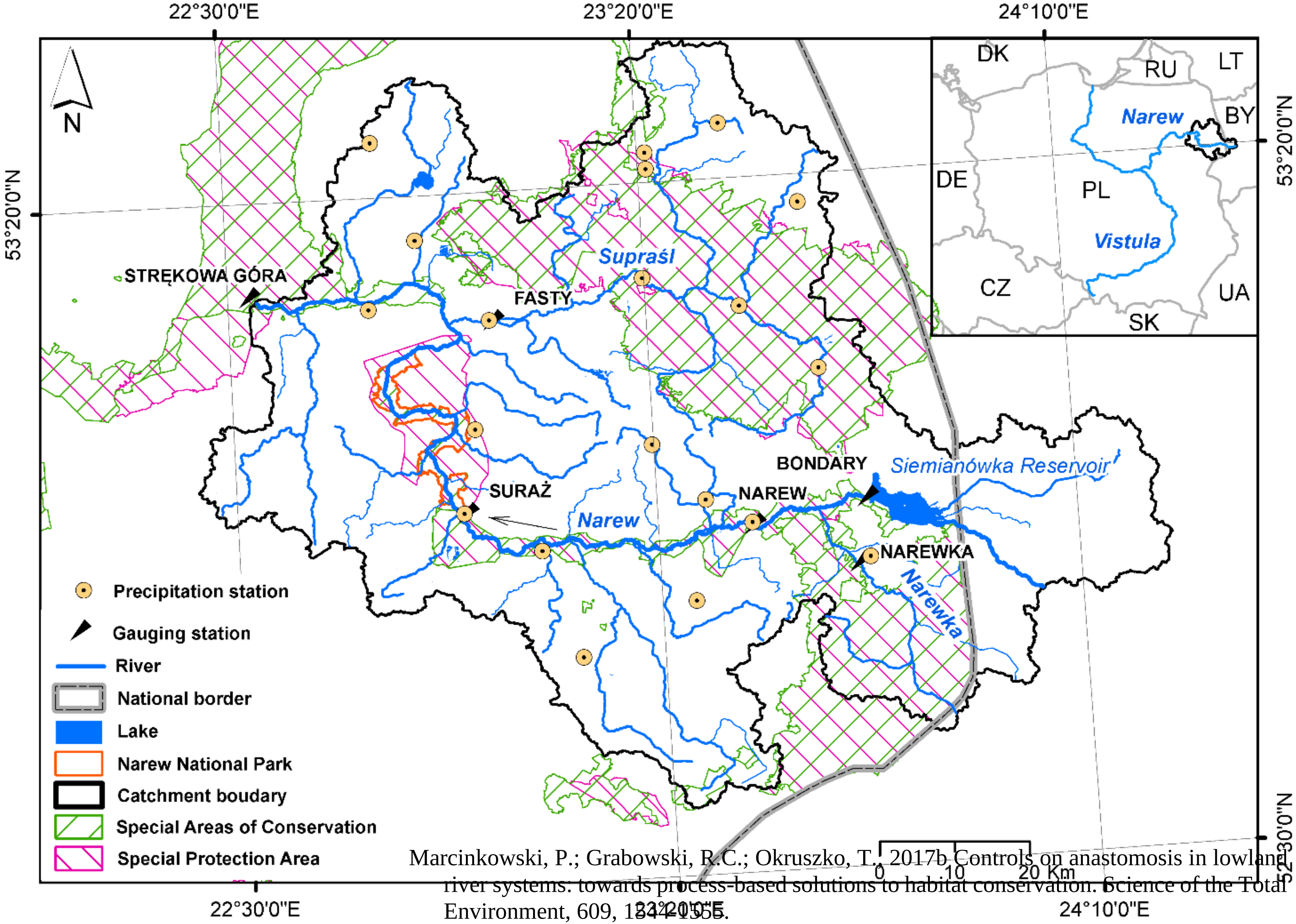


Variation of the flooded area and the water depth on the floodplain for different land use scenarios (MAX Q=229.20 m3/s. AVG Q=70.51 m3/s).

No Sc	Flooded area[km^2]	Average depth[m]	Flow condition
1	93.29	0.65	MAX
2	83.84	0.61	MAX
3	83.21	0.60	MAX
4	179.55	1.44	MAX
1	61.35	0.49	AVG
2	56.54	0.46	AVG
3	56.27	0.45	AVG
4	113.74	0.68	AVG

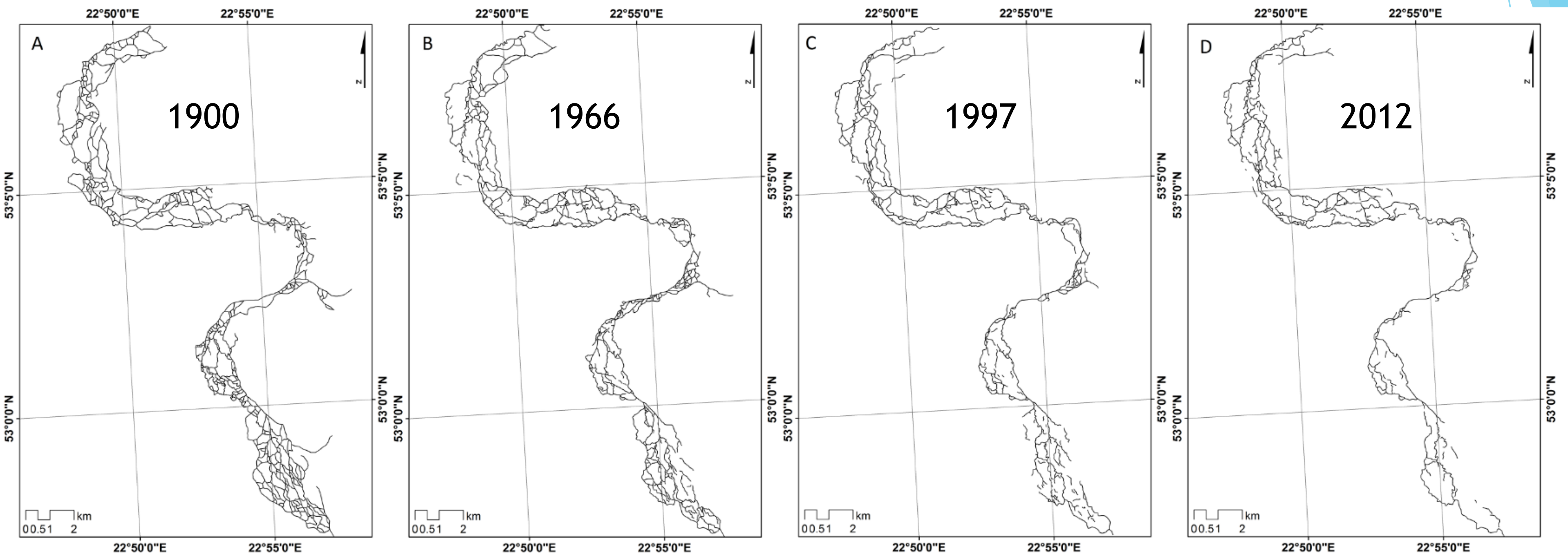
Restoration

Case study location



Marcinkowski, P.; Grabowski, R.C.; Okruszko, T., 2017b Controls on anastomosis in lowland river systems: towards process-based solutions to habitat conservation. Science of the Total Environment, 609, 1544–1555.

Temporal degradation



Statistics for channels evolution in the NNP.

Year	Width (m) (main channel)	Width (m) (side channels)	Share of main channel width in total width	Anabranching index	Length (km)
1900	No data	No data	No data	5.54	274.7
1966	22.9	51.3	31%	4.81	239.8
1997	24.1	31.4	43%	4.05	194.1
2012	24.6	16	61%	3.08	160.2

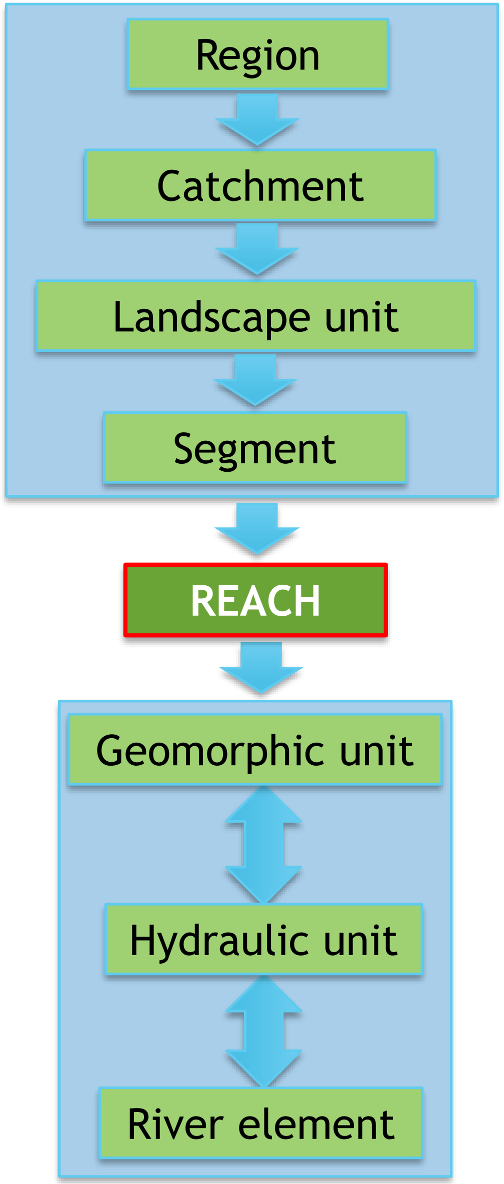
CHANGES THROUGH TIME

INFORMATION FROM THE PAST

Decades
aerial photography, airborne LiDAR and terrestrial laser scanning satellite imagery and multispectral data,

Centuries
documentary evidence (diaries, deeds, etc), land surveys, historical maps, topographic surveys of the river channel (e.g. repeated longitudinal profiles and cross sections) and terrestrial photography

Millenia
sedimentology, stratigraphy and geoarchaeology



PREDICTING THE FUTURE

Conceptual models

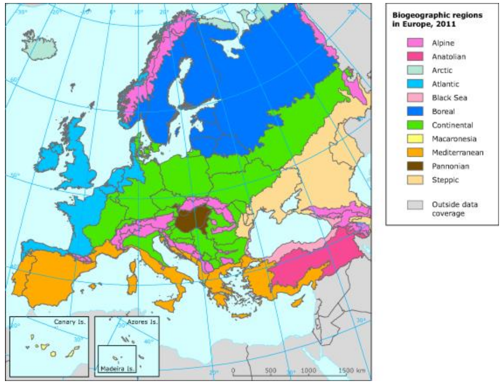
Statistical and Empirical Models

Analytical and Numerical Models

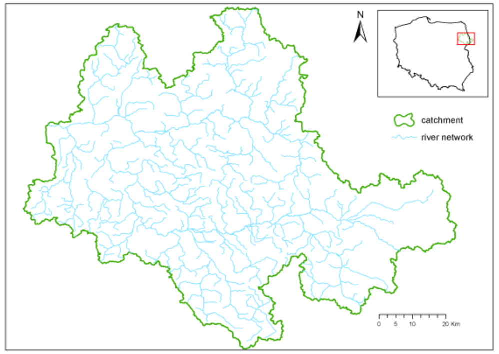
Physical Models

Stages of analysis (brief description)

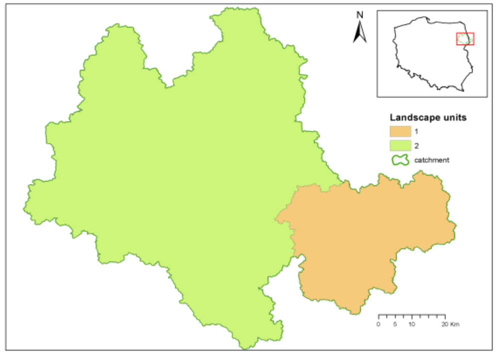
Biogeographic region (1)



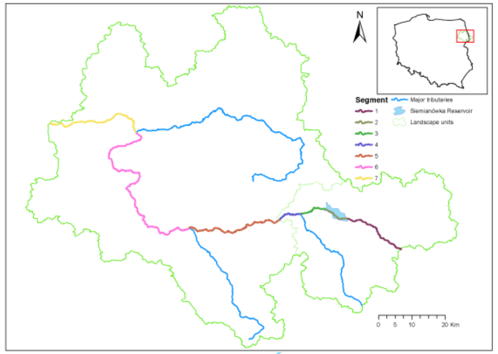
Catchment (1)



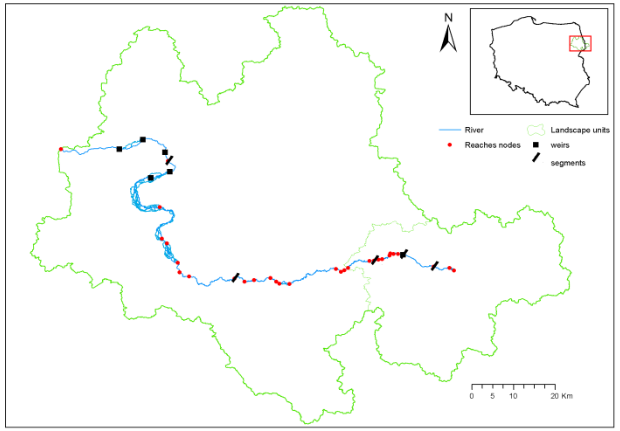
Landscape Units (2)



Segments (7)

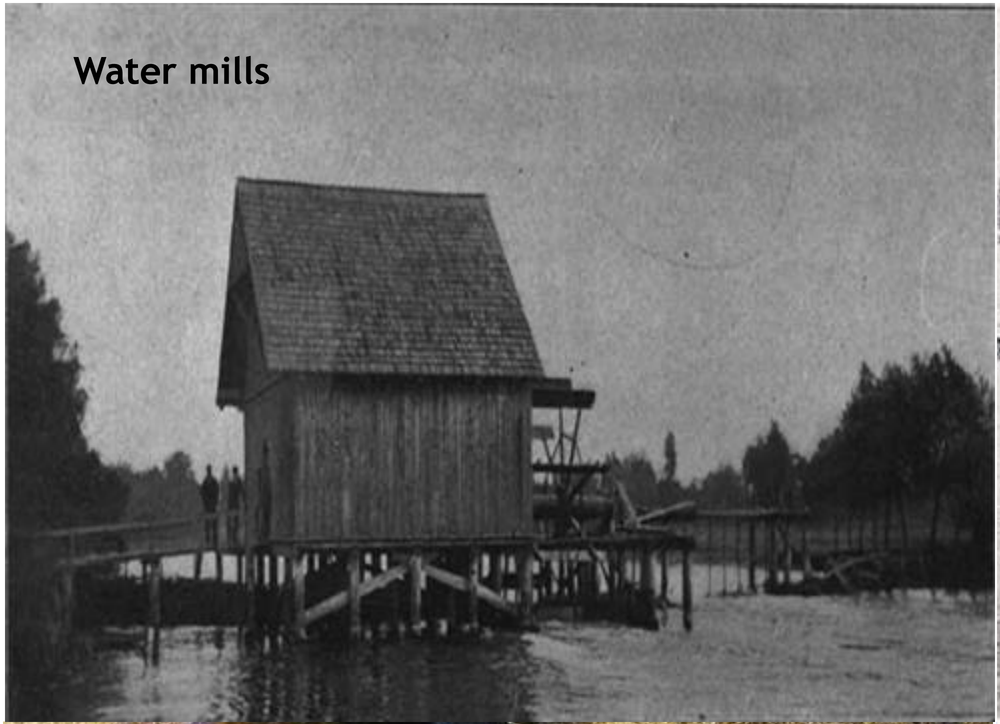


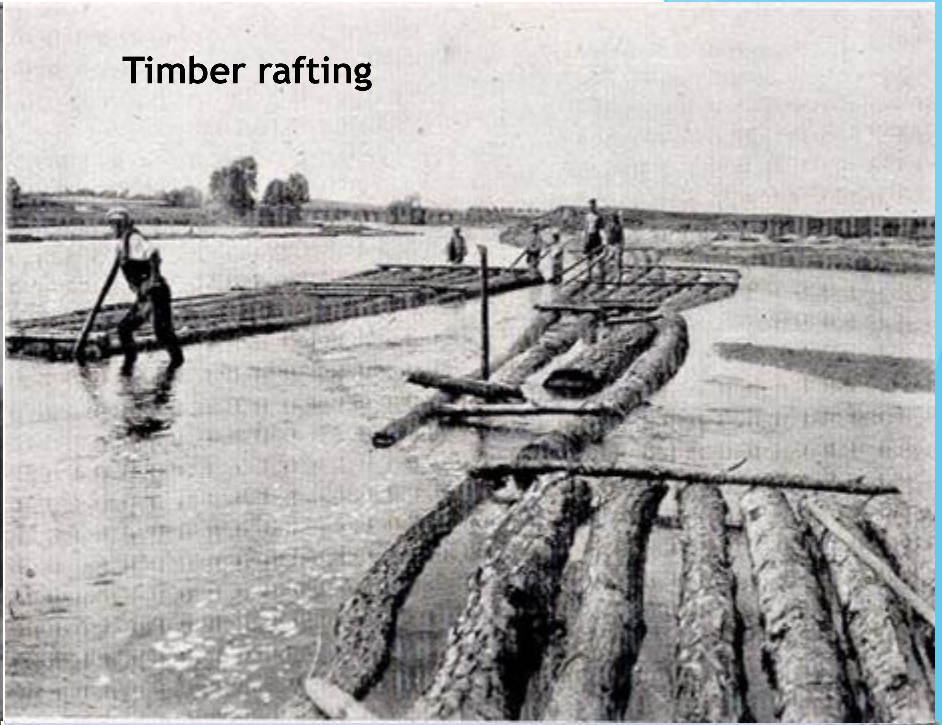
Reaches (35)



REFORM

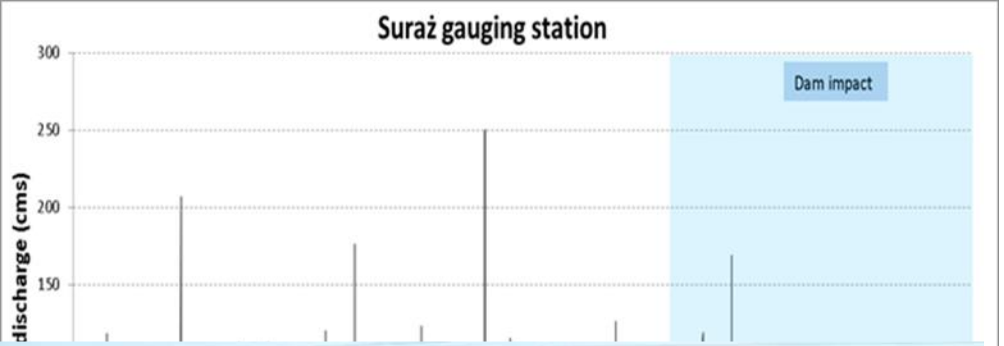
1816 SGGW

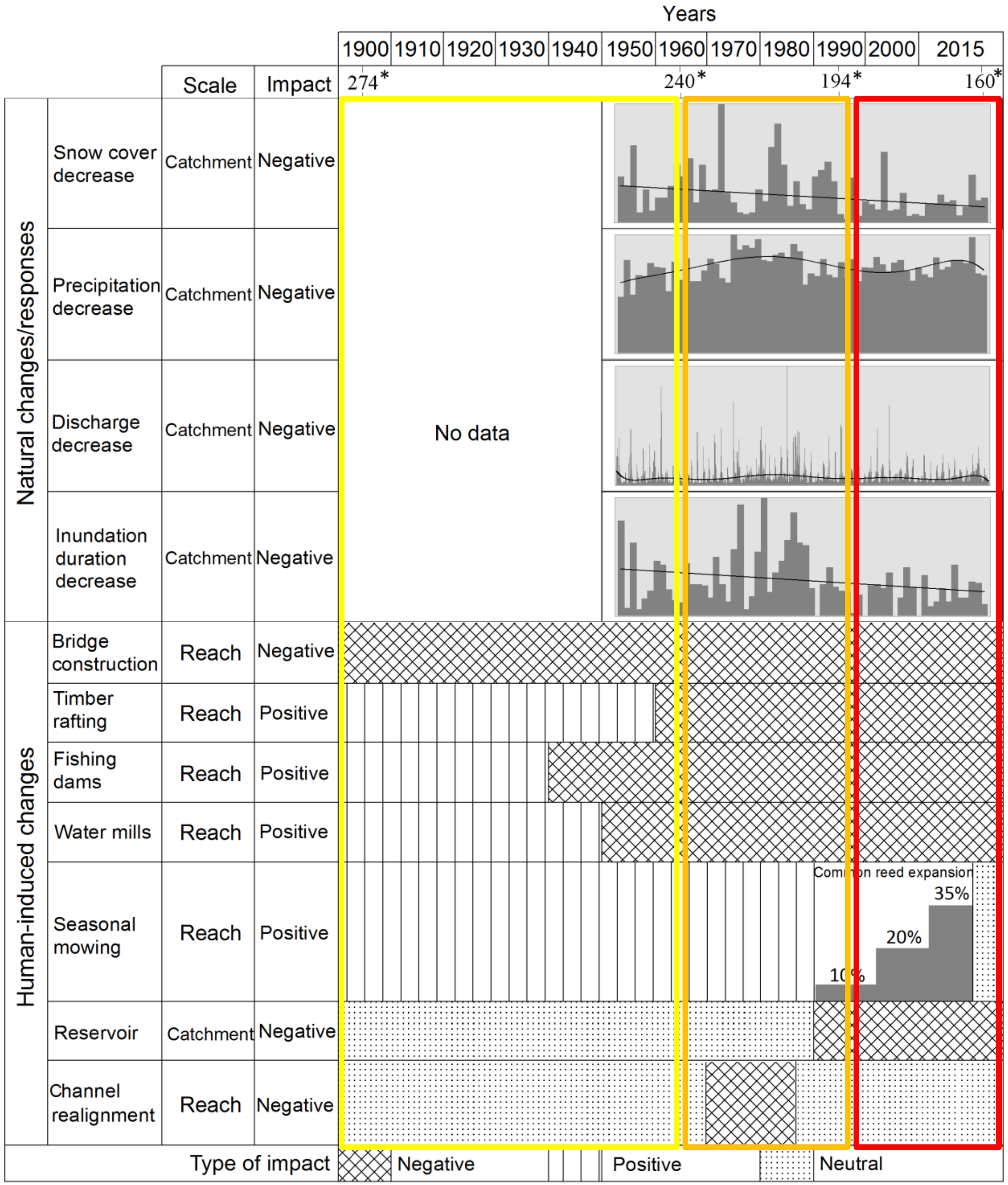

Water mills


Timber rafting

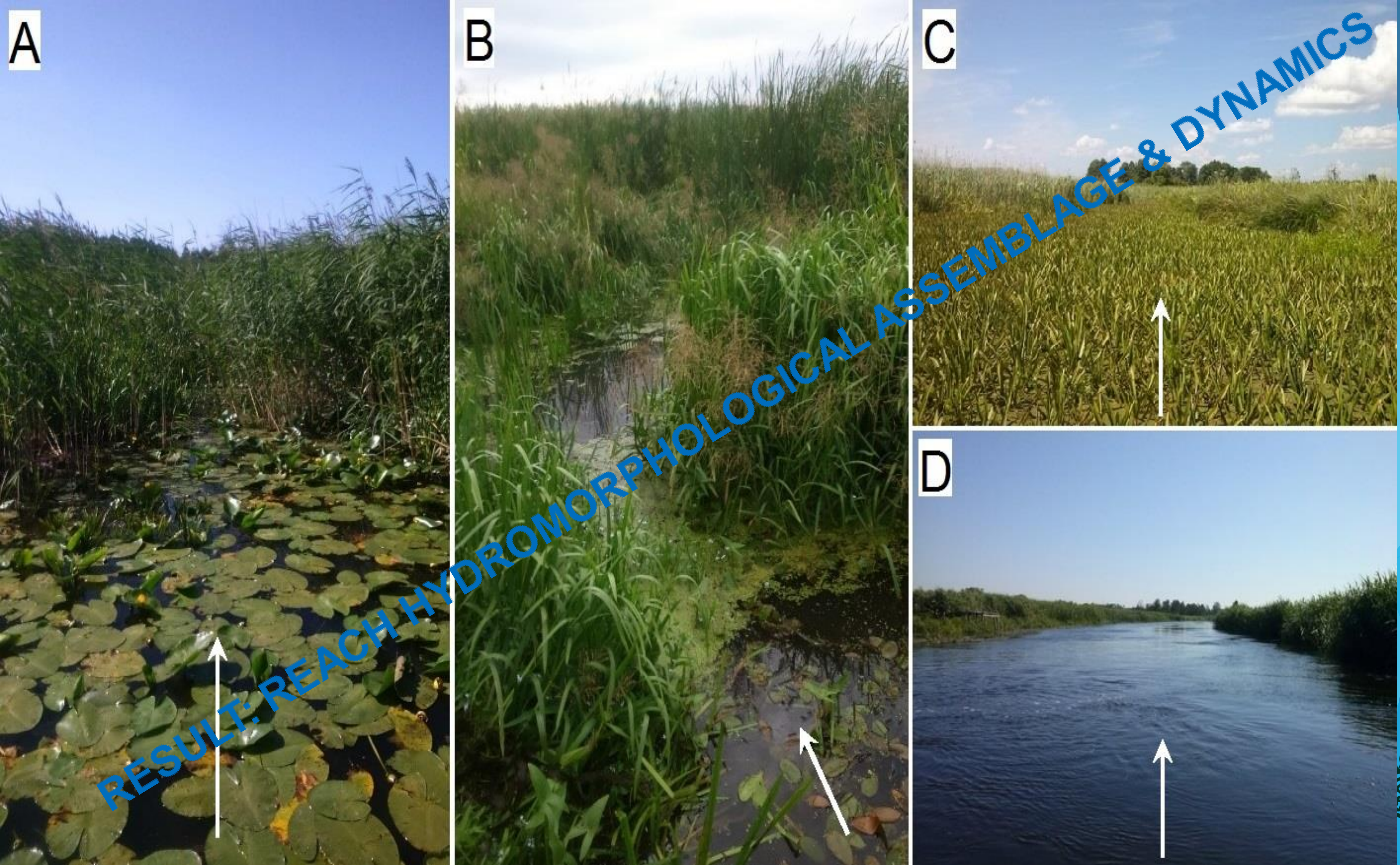

Fish dams


Cattle breeding


Suraż gauging station
Dam impact
discharge (cms)
300
250
200
150

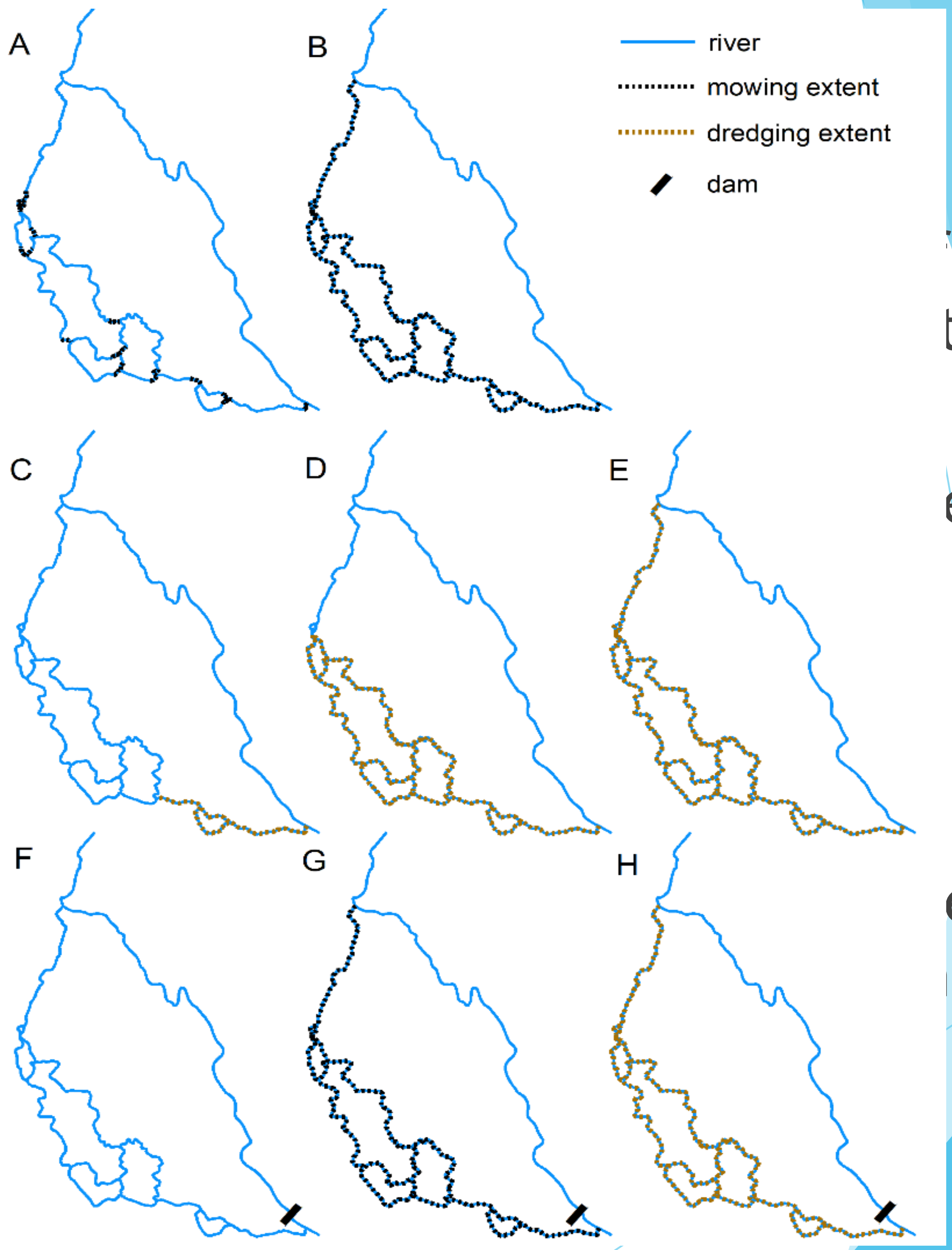

Years
1900 1910 1920 1930 1940 1950 1960 1970 1980 1990 2000 2015
274* 240* 194* 160*
Scale
Impact
Natural changes/responses
Snow cover decrease | Catchment | Negative
Precipitation decrease | Catchment | Negative
Discharge decrease | Catchment | Negative
Inundation duration decrease | Catchment | Negative
No data
Human-induced changes
Bridge construction | Reach | Negative
Timber rafting | Reach | Positive
Fishing dams | Reach | Positive
Water mills | Reach | Positive
Seasonal mowing | Reach | Positive
Common reed expansion
10%
20%
35%
Reservoir | Catchment | Negative
Channel realignment | Reach | Negative
Type of impact
Negative
Positive
Neutral

RESULT: REACH HYDROMORPHOLOGICAL ASSEMBLAGE & DYNAMICS



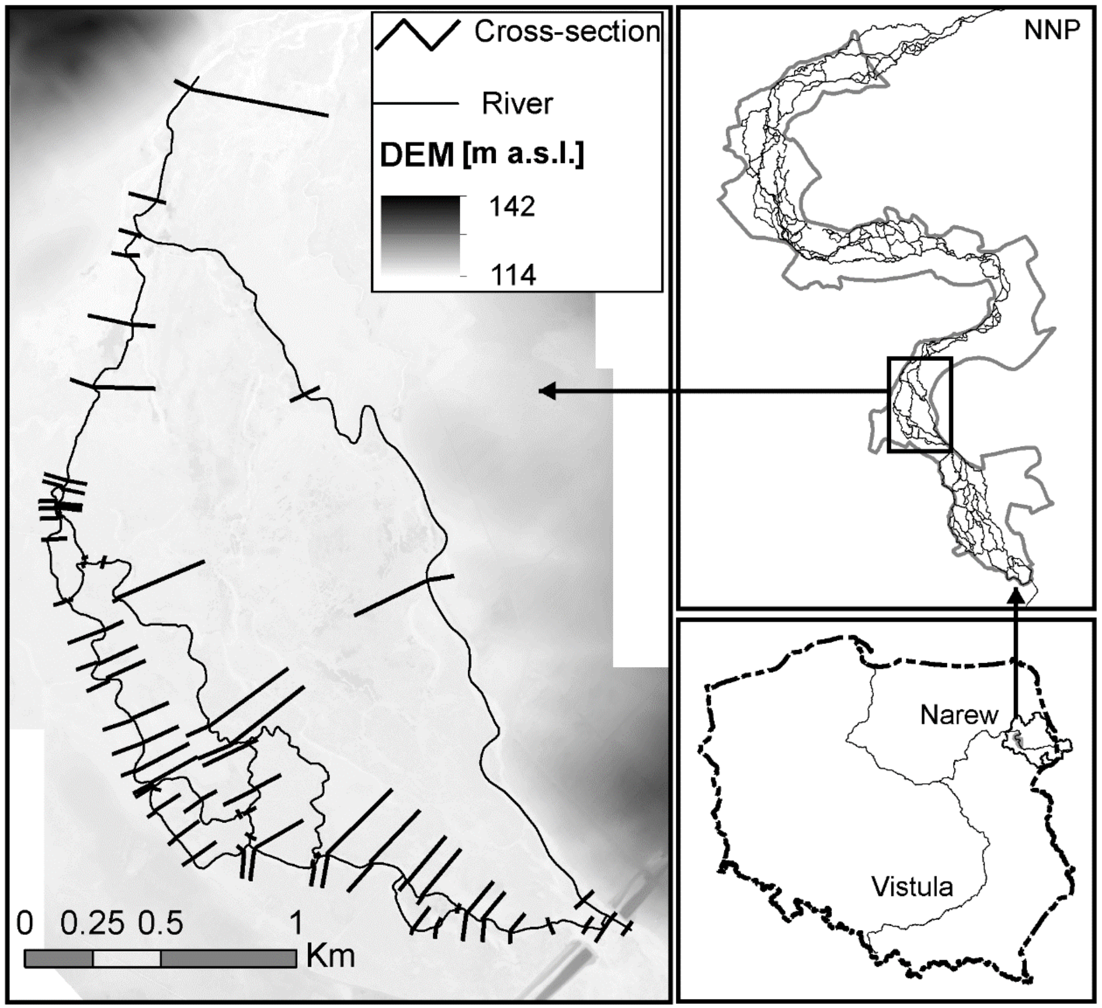
Conservation measures

- Park Protection Plan, approve… active protection measures in order … tem of the river segment
- Following measures, which mi… ed:
    - mowing
    - dredging
    - damming
- This issue rose the discussion … e processes. Thus some control … e further experiments.

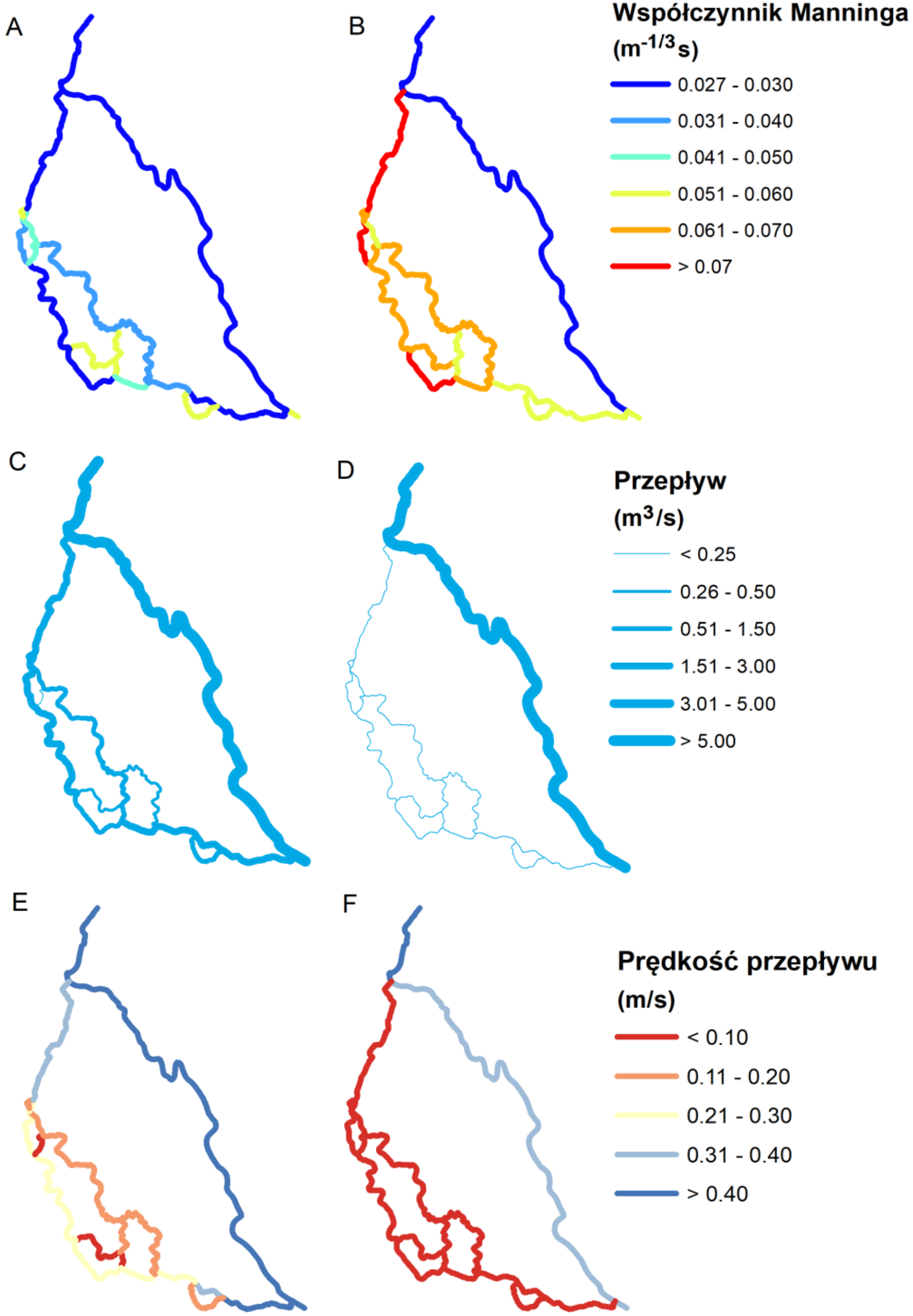


Hydraulic model

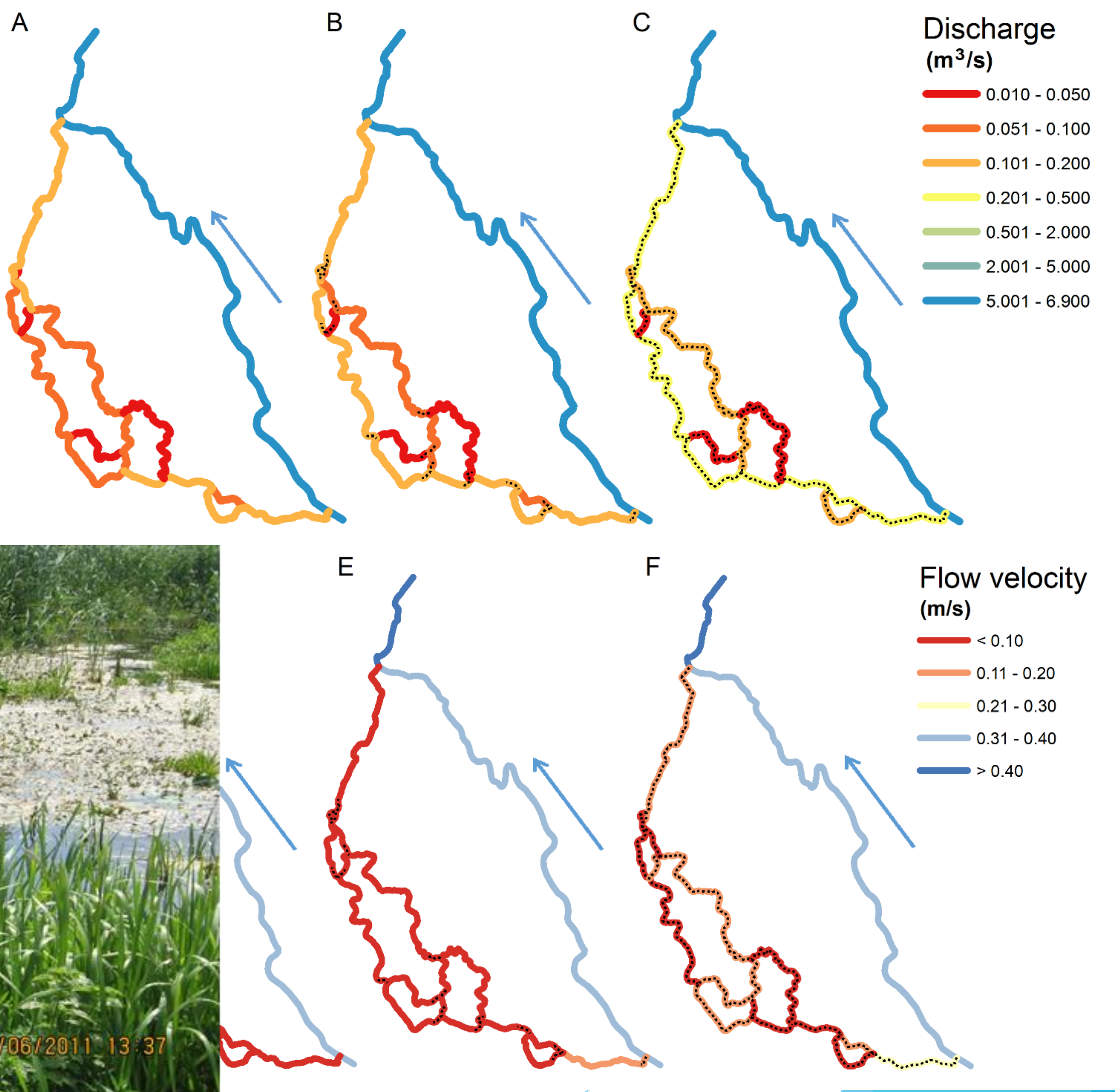
- Matlab designed,
- Steady flow conditions,
- One-dimensional flow is considered,
- River flow expressed in terms of energy conservation equation,
- Discharge within each river branch is uniform,
- Flow is subcritical.



Calibrated model

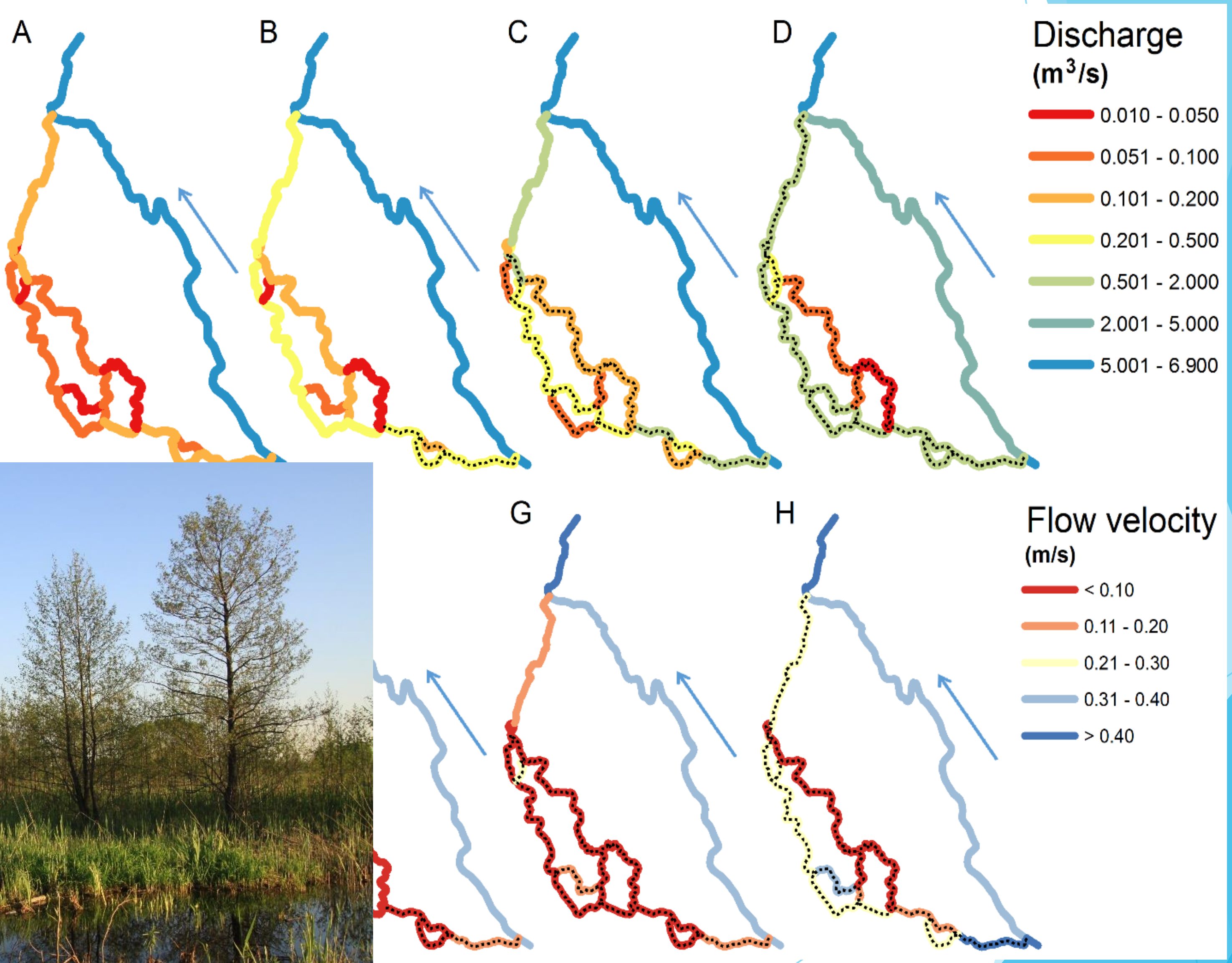


Mowing

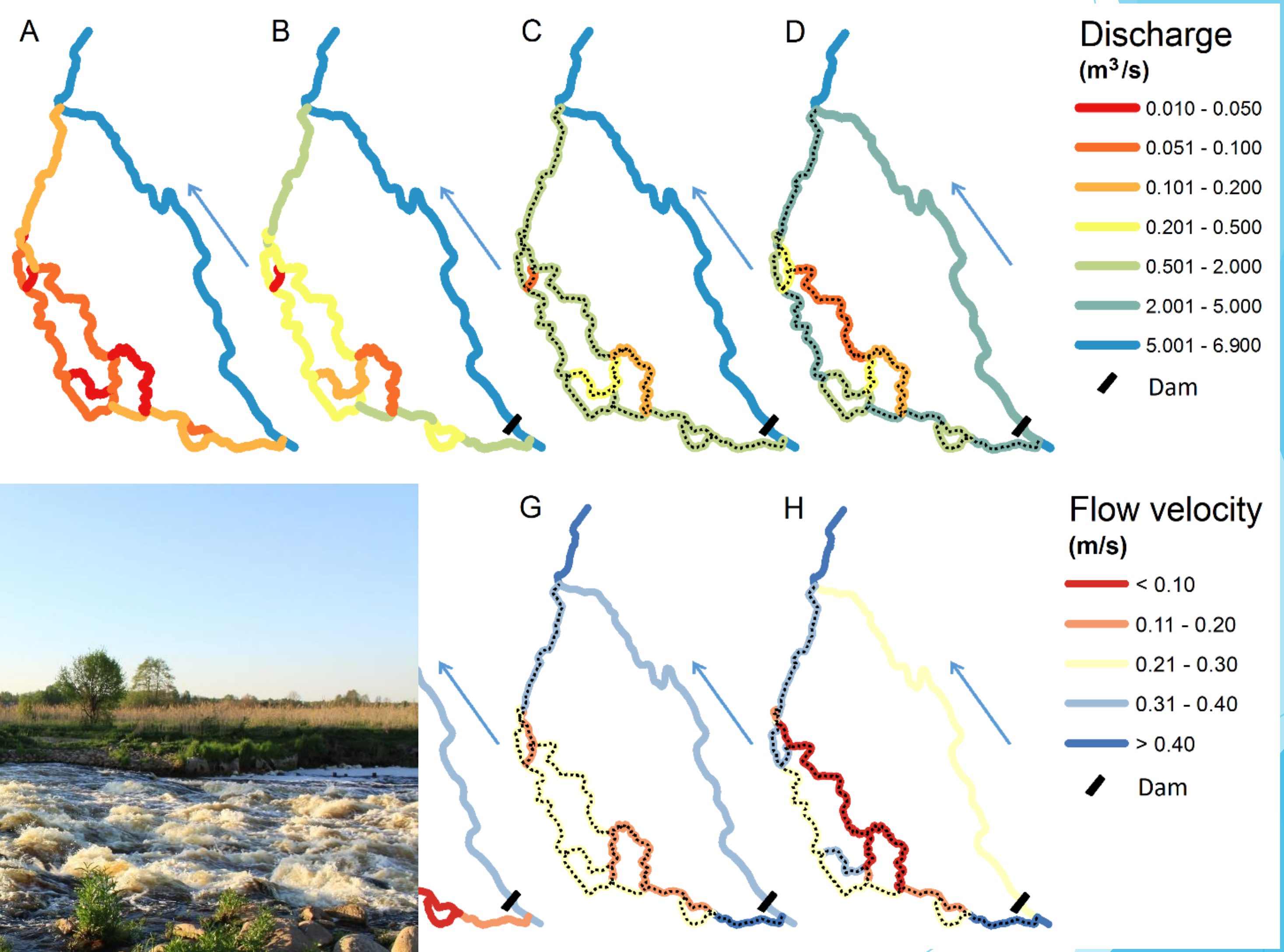

A
B
C
E
F
Discharge
(m³/s)
0.010 - 0.050
0.051 - 0.100
0.101 - 0.200
0.201 - 0.500
0.501 - 2.000
2.001 - 5.000
5.001 - 6.900
Flow velocity
(m/s)
< 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
> 0.40


28/06/2011 13:37

Dredging


A
B
C
D
G
H
Discharge
(m^3/s)
0.010 - 0.050
0.051 - 0.100
0.101 - 0.200
0.201 - 0.500
0.501 - 2.000
2.001 - 5.000
5.001 - 6.900
Flow velocity
(m/s)
< 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
> 0.40

Damming


A
B
C
D
G
H
Discharge
(m³/s)
0.010 - 0.050
0.051 - 0.100
0.101 - 0.200
0.201 - 0.500
0.501 - 2.000
2.001 - 5.000
5.001 - 6.900
Dam
Flow velocity
(m/s)
< 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
> 0.40
Dam

Predictions

PIKE
Esox lucius

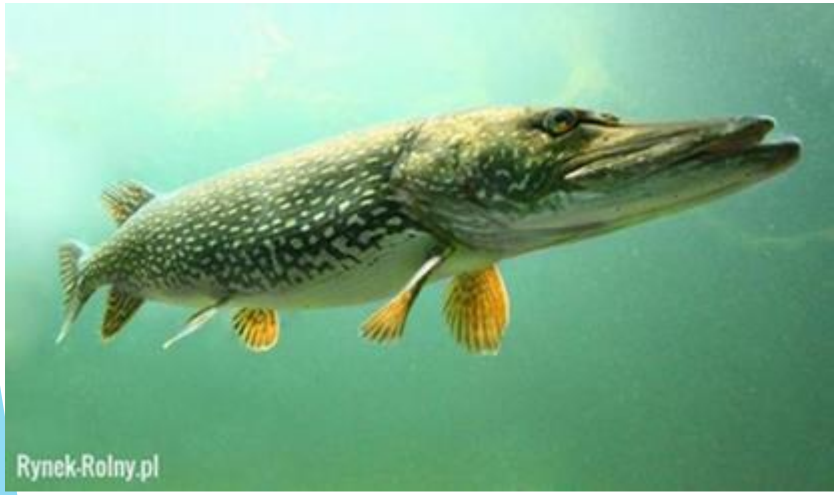
A species that migrates only to the nearest convenient habitats. Does not make spawning migrations.

CHUB
Squalius cephalus

A migratory species up to 50 km with greater spawning requirements.

ATLANTIC SALMON
Salmo salar

A species that migrates long distances to make the spawning migration.



After Joanna O,Keffee, PhD, research

WETLANDS FED BY SURFACE WATER

6430
Mountain herbs (Adenostylion alliariae) and riparian herbs (Convolvuletalia sepium)

91E0
Willow, poplar riparian forests,alder and ash forests (Salicetumalbo-fragilis, Populetum albae,Alnenion glutinoso-incanae,spring alder forests)

91F0
Riparian oak-elm-ash forests (Ficario-Ulmetum)

https://przyrodniczo.pl/siedliska/ziolorosla-gorskie/

Fot.Dorota Twardzik

Fot. Adrian Grycuk

GREY SEAGULL
Larus canus

Species under strict species protection in Poland*

Black-headed Gull
Chroicocephalus ridibundus

Species under strict species protection in Poland *

WHITE-FRONTED TERN
Sternula albifrons

Species under strict species protection, in addition, there is a ban on photography, filming or observation, which may cause frightening or disturbing *

* Ordinance of the Minister of Environment of October 6, 2014 on the protection of animal species (Dz.U. 2014 poz. 1348).

Input data

SWAT model simulation results
Calibrated and validated Soil and Water Assessment Tool (SWAT) model for the Vistula and Oder river basins

+

Climate change scenarios
Nine EURO-CORDEX regional climate models in two carbon concentration scenarios

=

Hydrological projections
Flow (m^3/s)

Species/ habitat	**Wetlands:** Habitats fed by surface water	**Fish:** pike, chub and atlantic salmon	**Birds:** gray gull, black-headed Gull , white-headed tern
Research area	Special Areas of Habitat Protection (SACs) Natura 2000 in the Vistula and Oder river basins.	Rivers in the Vistula and Oder basins	The middle course of the Vistula River
Analysis topic	Conservation status of wetland habitats, threat of drying out	Fish migration and spawning	Bird breeding success
Additional input data	Cross sections through riverbed, habitat status data	Literature review (flow preference)	Monitoring results (breeding success of birds)
Indicators	Average annual number of days when the flow exceeds the bank flow (NOD)	Selected Indicators of Hydrological Alteration (IHA)	Adjusted Indicators of Hydrological Alteration (IHA) indicators

Modelling Climate Change's Impact on the Hydrology of Natura 2000 Wetland Habitats in the Vistula and Odra River Basins in Poland
by Joanna O'Keeffe 1,*, Paweł Marcinkowski 1, Marta Utratna 1, Mikołaj Piniewski 1, Ignacy Kardel 1, Zbigniew W. Kundzewicz 2,3 and Tomasz Okruszko 1

Index-based analysis of climate change impact on streamflow conditions important for Northern Pike, Chub and Atlantic salmon
Joanna O'Keeffe, Mikołaj Piniewski, Mateusz Szcześniak, Paweł Oglęcki, Piotr Parasiewicz, Tomasz Okruszko

Future of birds nesting on river islands in the conditions of hydrological variability caused by climate change
Joanna O'Keeffe a b, Dariusz Bukaciński c, Monika Bukacińska c, Mikołaj Piniewski a, Tomasz Okruszko a

Research areas

Wetlands

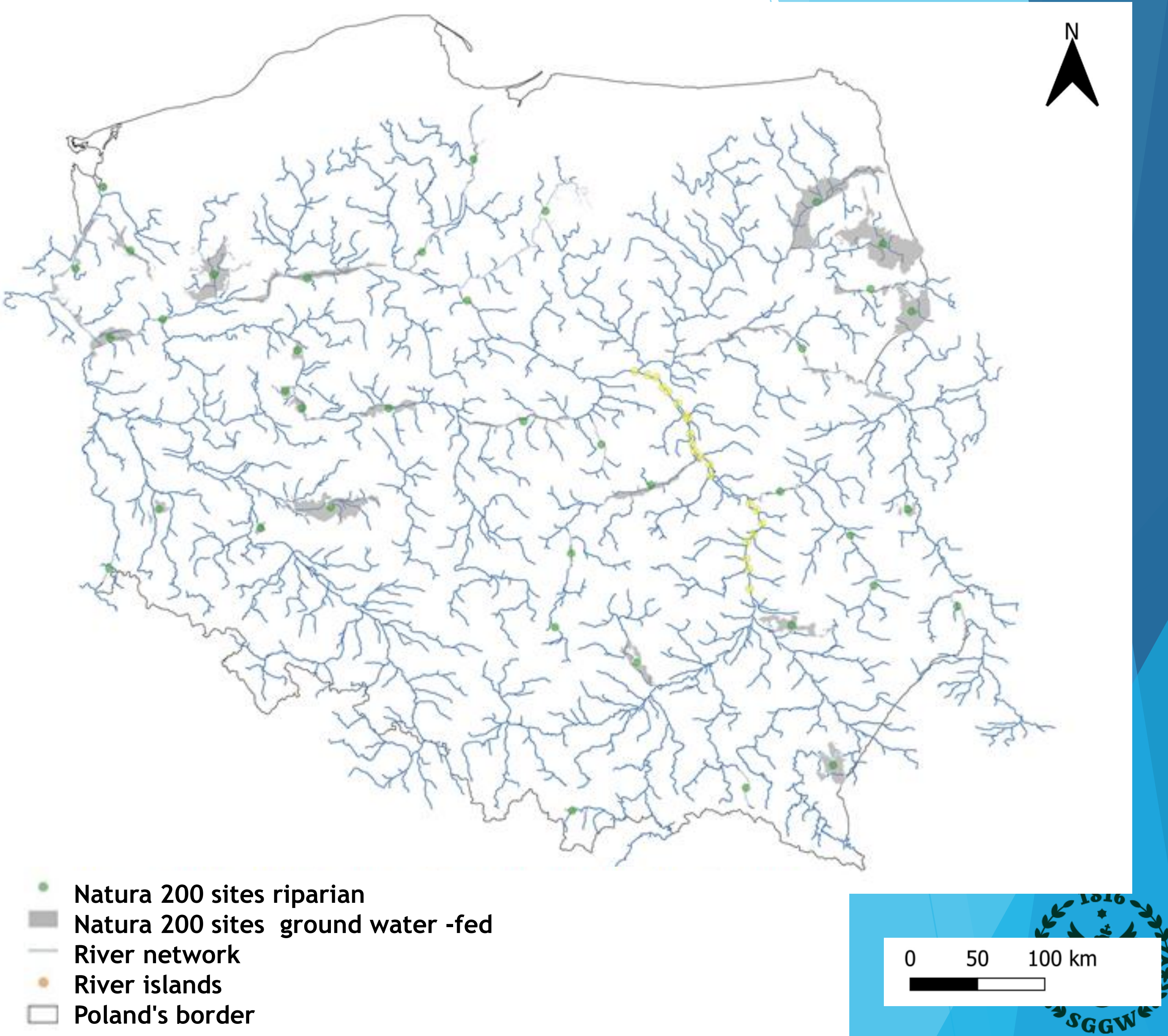
30 Natura 2000 Special Habitat Conservation Areas (SACs) with surface water-fed habitats.

Fishes

The Vistula and Oder river network consists of 2,633 sections.

Birds

22 island sites in the middle reaches of the Vistula River.



Cross-section analysis

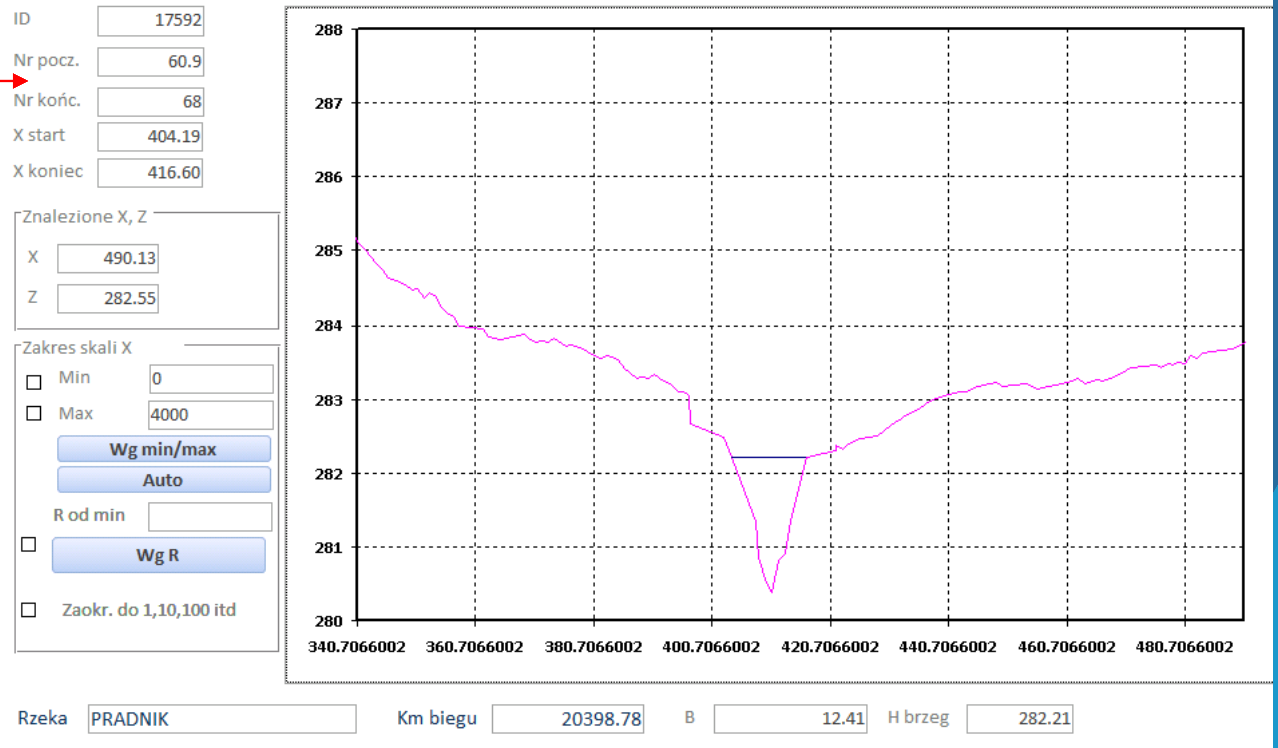
Visual assessment of bankfull level in cross sections (channel geometry obteined during geodesy field work)

Calculating bankful flow corresponding to bankfull level in the cross sections on the basis of Mannings formula.

Obtaining simulation results from SWAT on daily streamflow in subbasin

<u>When the daily streamflow (from SWAT) is greater than the streamflow at bankfull flow it will indicate a flood event.</u>

Analysis of duration (days) of streamflow above bankfull flow in given cross section paired with a Natura 2000 site, which is supposed to reflect conditions (water supply) of the surface water-fed wetlands.



Alignment of fish into 3 groups

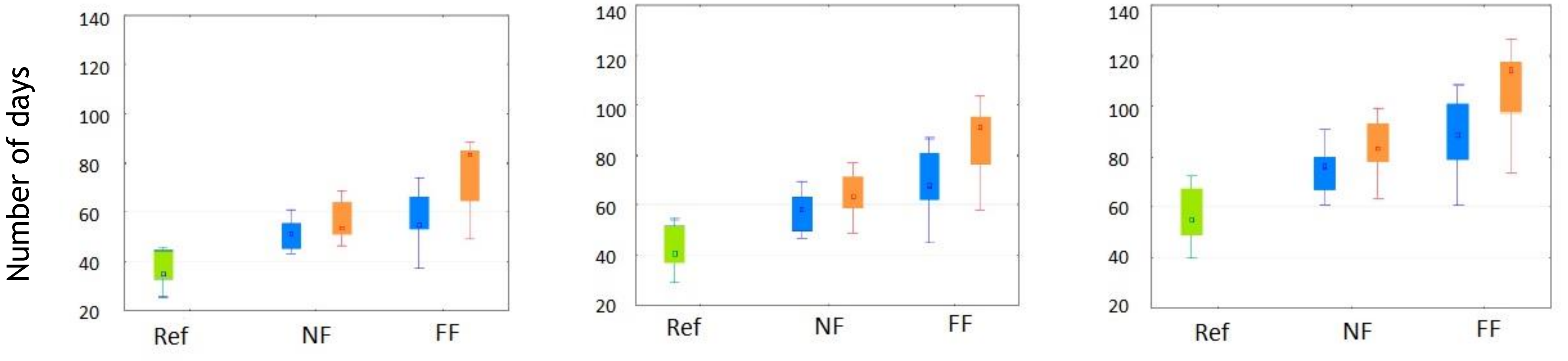
According to literature managing flows for multiple species is difficult and it is advised to develop a fish community typology that can represent the hydrological needs of those communities (Cowx et al. 2004).

Fish species can be grouped according to preference of: water temperature, river substrate, flow velocity, vegetation, river depth, migration distance etc.

Fish group	Characteristic	Species
1	Sedentary species that migrate in special situations, usually to the nearest suitable habitats. They don't carry out long spawning migration.	bleak (*Alburnus alburnus*), gudgeon *(Gobio gobio)*, **pike** (Esox luscious), perch (*Perca fluviatilis*), zander (*Sander lucioperca),* wels catfish (*Silurus glanis*), asp (*Aspius aspius*), Eurasian ruffe (*Gymnocephalus cernuus*), grayling (*Thymallus thymallus*).
2	Species migrating up to approx. 50 km with higher spawning requirements, more adjusted to migration.	roach (*Rutilus rutilus*), common bream (*Abramis bram),* white bream *(Blicca bjoerkna)*, brown trout (*Salmo trutta* m. *fario),* **chub** (*Squalius cephalus*), ide (or orfe) (*Leuciscus idus*).
3	Migratory species travelling long distance mostly to reach the spawning grounds (and possibly returning from them).	european eel (*Anguilla anguilla*), **sea trout** (*Salmo trutta* m. *trutta),* Atlantic salmon (*Salmo salar*), vimba bream (*Vimba vimba*).

Results (wetland habitats)

Predicted changes in average annual number of days with flooding



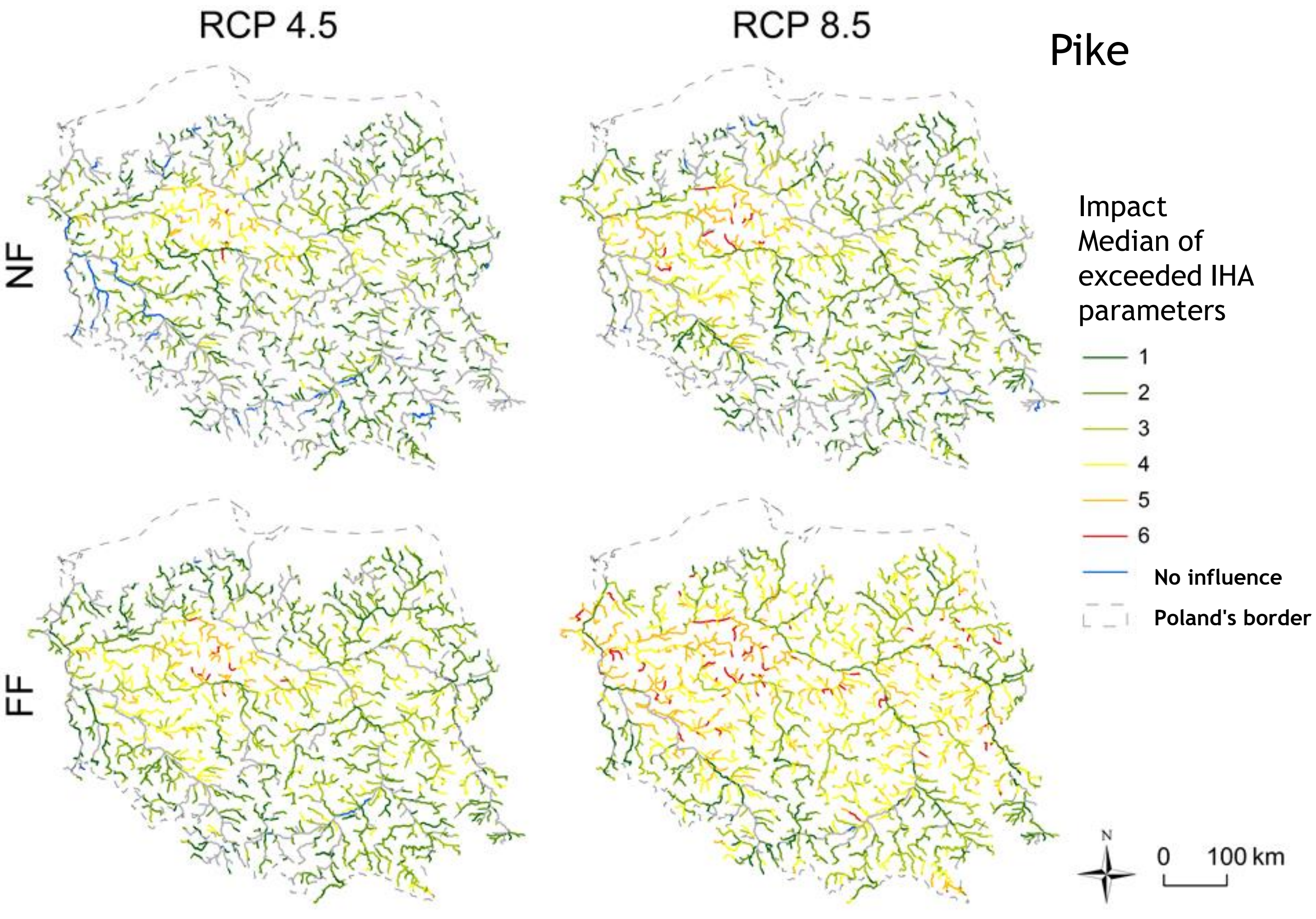
6430 mountain herbs and riparian herbs

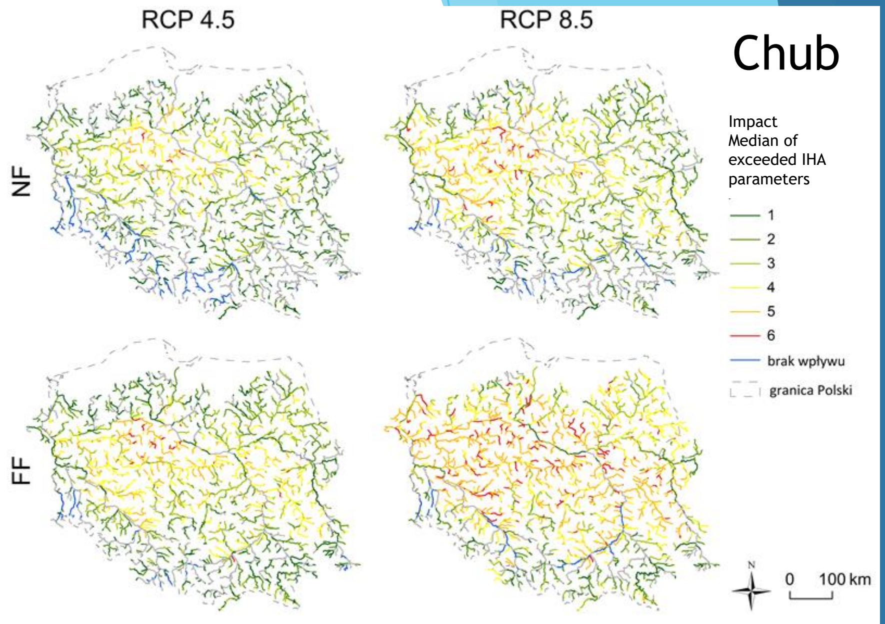
91E0 willow, poplar, alder and ash riparian forests

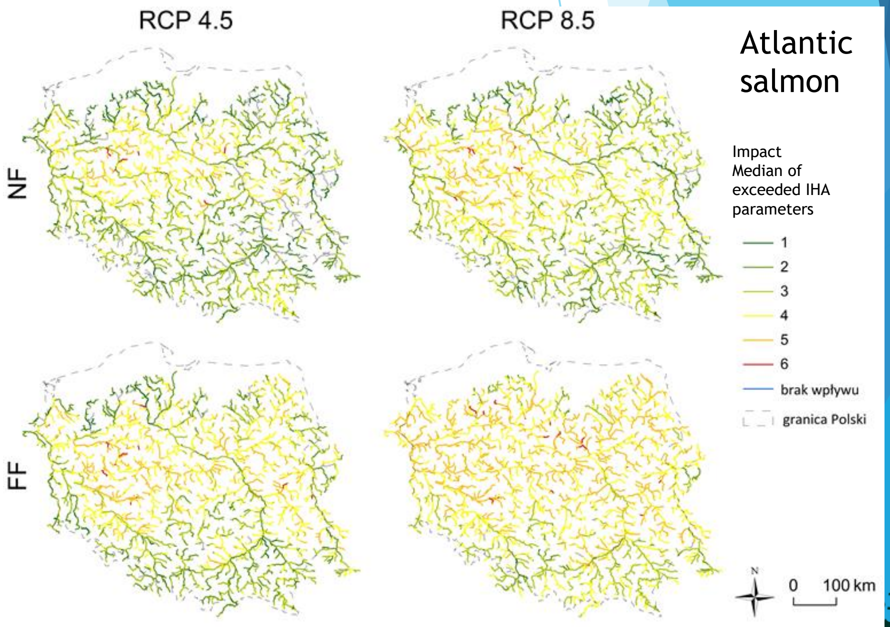
91F0 riparian oak-elm-ash forests

- For all three habitat types, the average number of days when flooding occurs more than doubles in the FF RCP 8.5 scenario compared to the reference period.

Results (selected fish species)





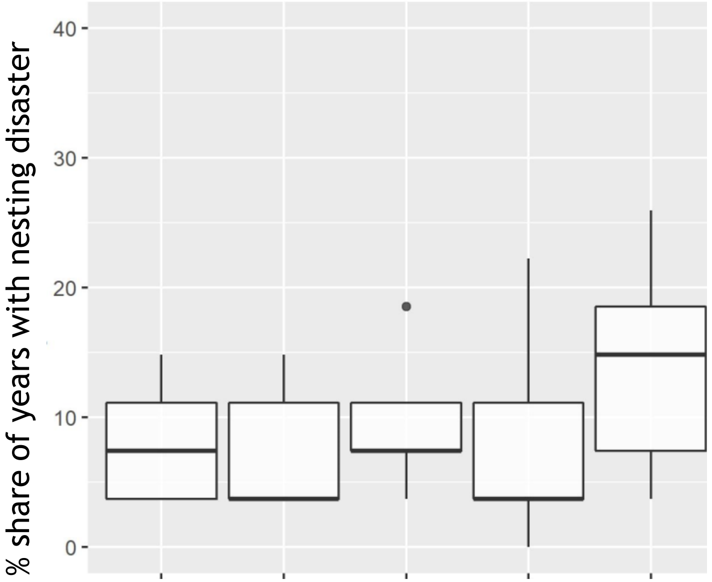


- Atlantic salmon - on average 97% of river sections influenced by climate change
- Pike and chub - from about 60 to 95% of river sections under the influence of climate change

Results (selected bird species)

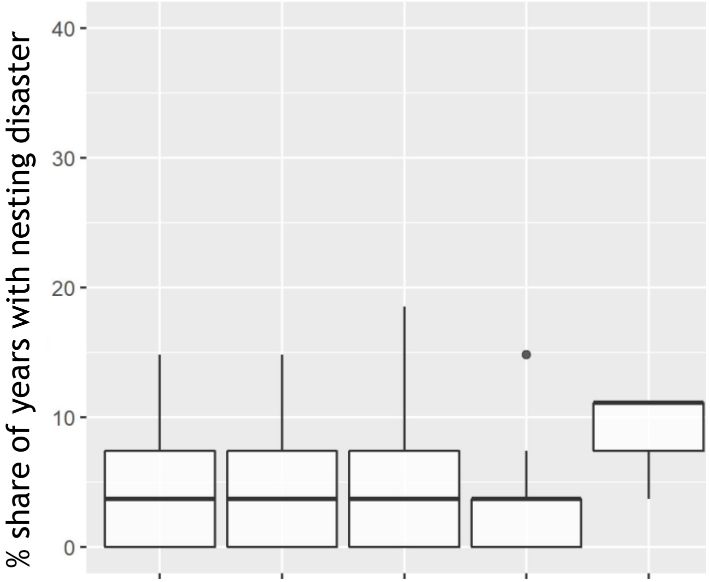
Share of years with nesting disaster

Grey Gull
Three-day moving average of maximum flow during the sensitivity period



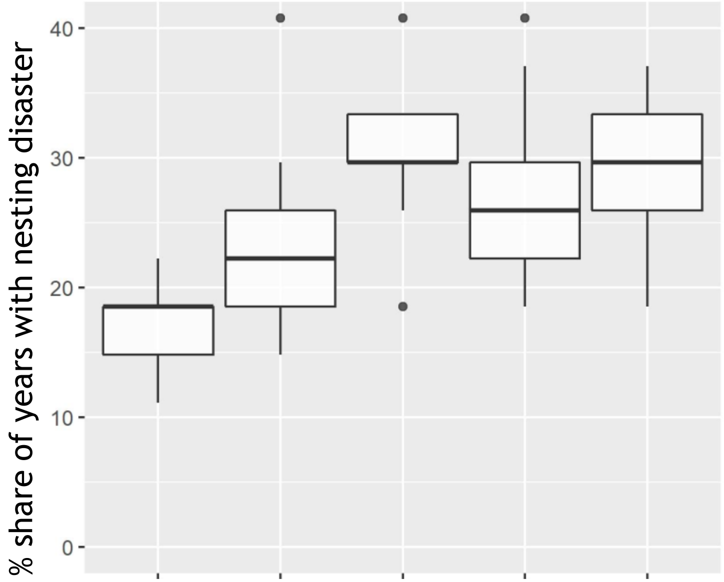
Ref NF4.5 FF4.5 NF8.5 FF8.5

Black-headed Gull
Average flow during incubation



Ref NF4.5 FF4.5 NF8.5 FF8.5

White tern
Average number of days in the sensitivity period when flow > 0.75 percentile



Ref NF4.5 FF4.5 NF8.5 FF8.5

- Increases in the proportion of years with a breeding catastrophe are most significant for the White tern (29.6% in FF 4.5 and FF 8.5)
- The proportion of years with CBS for the Black-headed Gull tern remains constant (median 3.7%) and increases to 11.1% in FF 8.5
- Projections for the Gray gull show decreases in NF and increases in FF relative to the reference scenario

Conclusions

- We do need the river ecosystem conditions concepts for setting the water management goals ….;
- …. and „River health” is not a Holy Graal;
- Hydrological and hydraulic models should be tailored when solving the practical questions;
- In many cases river segment brings too narrow perspective, **upscaling** is the term of today;
- Indicators form the information platform between the disciplines (before we use integrated models or AI-driven solutions) and between experts and the public.